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Design Partnership, Richmond, Va

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Kepone Incineration Test Program

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The Kepone Incineration Test (KIT) program was undertaken to evaluate incineration as a method of destroying Kepone and Kepone-containing materials and to determine the range of operating variables required for complete destruction. The program was divided into two phases: (a) experiments involving the direct injection of low BTU solutions of Kepone into the afterburner, and (b) experiments involving the co-incineration of sewage sludge and various amounts of Kepone injected into a rotary kiln. Each phase was designed so that succeeding experiments involved longer amounts of Kepone and/or alterations in afterburner temperature and residence time.

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COMMONWEALTH of VIRGINIA

JAMES B. KENLEY, M.D.
COMMISSIONER

Department of Health
Richmond, Va. 23219

SUBJECT: KEPONE INCINERATION TEST

25 March 1977

Dr. Frank Whitmore
Versar, Inc.
6621 Electronic Drive
Springfield, Virginia 22151

Dear Dr. Whitmore:

We have received the analyses of the blood samples collected before and after the Kepone Incineration Test Program on personnel who were to work on the test program. This is to advise that all samples were negative and no Kepone was detected.

I would appreciate it if you would pass this information on to the appropriate personnel.

Sincerely,

Eric H. Bartsch

Eric H. Bartsch, P. E., Director
Bureau of Sanitary Engineering

EHB/c

EPA-600/2-78-108
May 1978

KEPONE INCINERATION TEST PROGRAM

by

Bruce A. Bell
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Richmond, Virginia 23226

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Springfield, Virginia 22151

Grant No. R-805112

Project Officer

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Municipal Environmental Research Laboratory
Cincinnati, Ohio 45268

This study was conducted
in cooperation with
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Department of Health
Richmond, Virginia 23219

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution, and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research, a most vital communications link between the researcher and the user community.

The aftermath of the release of large quantities of Kepone to the environment in Hopewell, Virginia, has resulted in the collection of Kepone and Kepone-contaminated materials for which a safe, economical, and environmentally acceptable method of destruction is required. The study reported here presents the results of a pilot-scale study of incineration of Kepone.

Francis T. Mayo, Director
Municipal Environmental Research
Laboratory

SUMMARY

One result of Kepone production operations by the Life Sciences Corporation in Hopewell, Virginia, has been an accumulation of large amounts of Kepone and Kepone-contaminated materials that must be disposed of. Work by Design Partnership of Richmond, Virginia, under contract to the Commonwealth of Virginia, has indicated that thermal destruction is the safest and most convenient way to dispose of these materials. In addition, Rubey and Duvall(1) have shown that Kepone is thermally destroyed at temperatures on the order of 350° to 400°C but that several thermal degradation products are stable to temperatures of 900°C.

The Kepone Incineration Test (KIT) program was undertaken to evaluate incineration as a method of destroying Kepone and Kepone-containing materials and to determine the range of operating variables required for complete destruction. The program, undertaken at the Surface Combustion Division of Midland-Ross Corporation in Toledo, Ohio, was divided into two phases: (a) experiments involving the direct injection of low BTU solutions of Kepone into the afterburner, and (b) experiments involving the co-incineration of sewage sludge and various amounts of Kepone injected into a rotary kiln. Each phase was designed so that succeeding experiments involved larger amounts of Kepone and/or alterations in afterburner temperature and residence time.

The management structure of the KIT program worked well and contributed much to completion of the program. A committee of representatives from the federal, state, and local agencies whose responsibilities include air and water quality was organized and designated the Burn Authority. This group, which had at least one member on the site at all times during the tests, had final authority to allow the experiments to continue, to cease, or to be modified in order to meet the pre-assigned standard that under no circumstances would Kepone emission of 1 microgram per cubic meter be reached. The Burn Authority was aided by the Experimental Management Group, which was made up of one senior member from each participating contractor. This latter group had the additional responsibility of conducting the experiments and reporting the results to the Burn Authority. The Health and Safety Group saw that the facility was properly prepared to isolate the contaminated areas and was responsible both for training all personnel in the use of safety equipment and for monitoring the use of safety equipment. The Public Information Group had the responsibility for keeping the press and the interested public completely informed as to the program.

The experimental procedures are outlined in Section 5 of this report and fully treated in Appendix D. The Burn Authority and the Experimental Management Group altered procedures when it became apparent that the high-level in-

jection experiments could result in emissions approaching the preset allowable limit.

The pertinent experimental results obtained in the KIT program follow.

RESULT OF KEPONE INCINERATION EXPERIMENTS

Experiments	Kepone feed rate (g/min)	Total feed time (min)	Total Kepone fed (g)	Stack emission concentration (g/m^3)	Total stack output (g)	After-burner temp. (°C)
Injection runs	Acetic acid					
1	only	—	—	--	--	1260
2	1.67×10^{-5}	130	2.16×10^{-3}	ND	ND	1260
3	1.67×10^{-5}	135	2.25×10^{-3}	ND	ND	1093
4	1.67×10^{-2}	100	1.67	ND*	ND*	1093
5	1.50	115	172.5	5.35×10^{-8}	1.76×10^{-4}	1093
Sludge runs	Background					
6+	Toledo sludge	120	—	2.96×10^{-7}	7.1×10^{-4}	1093
7	only	120	--	ND	ND	1093
8	5.68	315	1789	1.7×10^{-8}	1.85×10^{-4}	1149
9	5.68	240	1354	2.4×10^{-8}	1.85×10^{-4}	1093
10	5.68	220	1241	2.55×10^{-8}	1.53×10^{-4}	1038
11	24.2	165	3995	2.95×10^{-8}	1.67×10^{-4}	1093
Totals	—	—	8553	—	1.58×10^{-3}	—

* There was an apparent Kepone peak on the extract from the filter--a peak that disappeared on base partitioning of the extract.

+ Experiment 6 was run with a contaminated scrubber (25 ppb) in an attempt to determine the cause of the high emission in the previous experiment.

For each experiment the efficiency of destruction exceeded 99.9999 percent. Health and safety procedures were adequate in that no individual was exposed to detectable levels of Kepone, as indicated by before and after blood tests, and no escape of Kepone into the ambient air was detected by air samplers on the premises.

The recommendations that derive from these experiments may be summarized as follows:

(1) The incinerator system should consist of a fume incinerator capable of sustained operation at about 1000°C and with sufficient volume

to allow residence times of about 2 seconds, a pyrolyzer capable of substained operation at about 450°C to vaporize and (probably) to decompose the Kepone partially, a strongly basic (pH above 9.0) scrubber system, and a suitable pollution control system. The entire system must be designed to operate at a significantly negative pressure and should be fitted with sensors that detect and warn when these conditions are not met.

(2) Provision should be made to feed solid materials directly into sludge because the use of acetic acid seems to introduce complications for large-scale operations. The direct feed of low-BTU solutions into the incinerator without the mediation of the pyrolyzer should be possible even though the particular combination of conditions at the experimental site seems to indicate that this is not a useful approach.

(3) The facility should have a full-time safety engineering group on its staff. The experience at Midland-Ross suggests that even though the personnel have been carefully trained in the need for and the proper use of protective equipment, they need to be reminded to use such equipment properly. In addition, the acetic acid spill that occurred during the KIT program points out the need for prompt action in the event of an accident--action that can be properly initiated only by a professional safety engineer.

(4) The incineration system used for the large-scale destruction of Kepone and Kepone-bearing materials should be separated into areas that could be heavily contaminated and those areas that could not. The introduction of protective gear could thus be controlled to minimize both the equipment needed and the time and efficiency penalties exacted by its use.

(5) The facility should provide for the retention of all liquid and solid effluent streams until analysis shows they are not contaminated. In this context, there should be a well designed sampling arrangement built into the plant and a suitably designed sampling program. This sampling program should be fully supported by onsite analytical capability suitable for trace analysis.

(6) For successful operation, a public information program should be an integral part of the provisions for final disposal.

(7) The KIT program did not include the determination of parameters for materials used, the precise geometry of a suitable incinerator system, or even the possible performance penalties exacted by the use of safety equipment. Such matters were left for later design studies and should be evaluated.

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E.H. Bartsch, Director, Bureau of Sanitary Engineering,
    Department of Health, Virginia
R.A. Carnes, Environmental Scientist, Solid and Hazardous
    Waste Research Division, MERL, USEPA
D. Krygielski, Engineer, Toledo Pollution Control Agency
K.J. Klepitsch, Jr., Chief, Solid Waste Branch, USEPA,
    Region V
Julius Foris, Chief, Division of Technical Support Operations,
    Office of Air Pollution Control, Ohio EPA

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SECTION 1

INTRODUCTION

The serious environmental contamination produced by the Kepone manufacturing operations of Life Sciences Corp., of Hopewell, Virginia, has resulted in the necessity for the disposal of large quantities of Kepone and Kepone contaminated water, soil, sewage sludge, and a variety of other materials. A strong concensus of opinion, supported by a study conducted by Design Partnership of Richmond, Virginia, has developed that the safest, most economical and most convenient method of disposal of these materials is by thermal destruction. This decision is strongly supported by the laboratory studies of Duvall and Rubey(1) which have shown that Kepone is thermally unstable at temperatures above 350°C and that even the most thermally stable of its breakdown or thermal rearrangement products (hexachlorobenzene) is unstable at temperatures on the order of 900°C.

The general difficulties inherent in the extrapolation of laboratory scale data to large scale operations made it imperative that an intermediate (pilot) scale test series be carried out. This pilot scale series would serve the dual purpose of extending and confirming the Rubey and Duvall(1) findings, while at the same time define the necessary range of operating parameters for the safe and complete destruction of Kepone and its products. The desirable physical arrangement of equipment for these pilot scale tests would consist of a rotary kiln for volatilization in conjunction with an afterburner capable of operating at temperatures of the order of 1100°C with residence times of the order of several seconds. In addition, the installation should possess adequate air pollution control equipment. A search revealed that such an installation was not available within the Commonwealth, but that the facility at Midland-Ross, Surface Combustion Division in Toledo, Ohio was available.

In the course of negotiations with Surface Combustion, it became obvious that the wide publicity that had been accorded the disastrous effects that resulted from the exposure of the employees of the Life Sciences Co. had generated a situation which made it very difficult for the officials of the City of Toledo and the State of Ohio to grant the necessary permission for the tests to take place. The result of this concern was an extended series of meetings with representatives of the responsible governmental bodies. From these meetings a detailed plan of operations was evolved that all parties agreed would allow the necessary tests to be carried out under conditions that would guarantee the safety of the surrounding community as well as that of the operating personnel. Specifically, the result of these deliberations was the generation of a unique management structure which provided the responsible governmental officials with a strong measure of control of the day-to-day operations. In addition, a very detailed protocol for the experimental program was constructed.

PROGRAM MANAGEMENT

After much discussion, the program management structure as outlined in Figure 1 was evolved as offering the strongest possible control over the program by both the responsible governmental bodies and by the technical staff that would be assigned to the program. Briefly, the plan was for the detailed experiments to be carried out under the direction of the Experimental Management Group under stringent safety procedures established by and monitored by the Health and Safety Group. The results of each experiment were then presented to the Burn Authority along with any necessary additonal information. The latter group was then empowered to make the decision as to whether the program should proceed on the basis of the protocol, or should be modified. The results of each experiment and the resulting Burn Authority decision were then to be transmitted to the interested public through the medium of the Public Information Group.

The Burn Authority

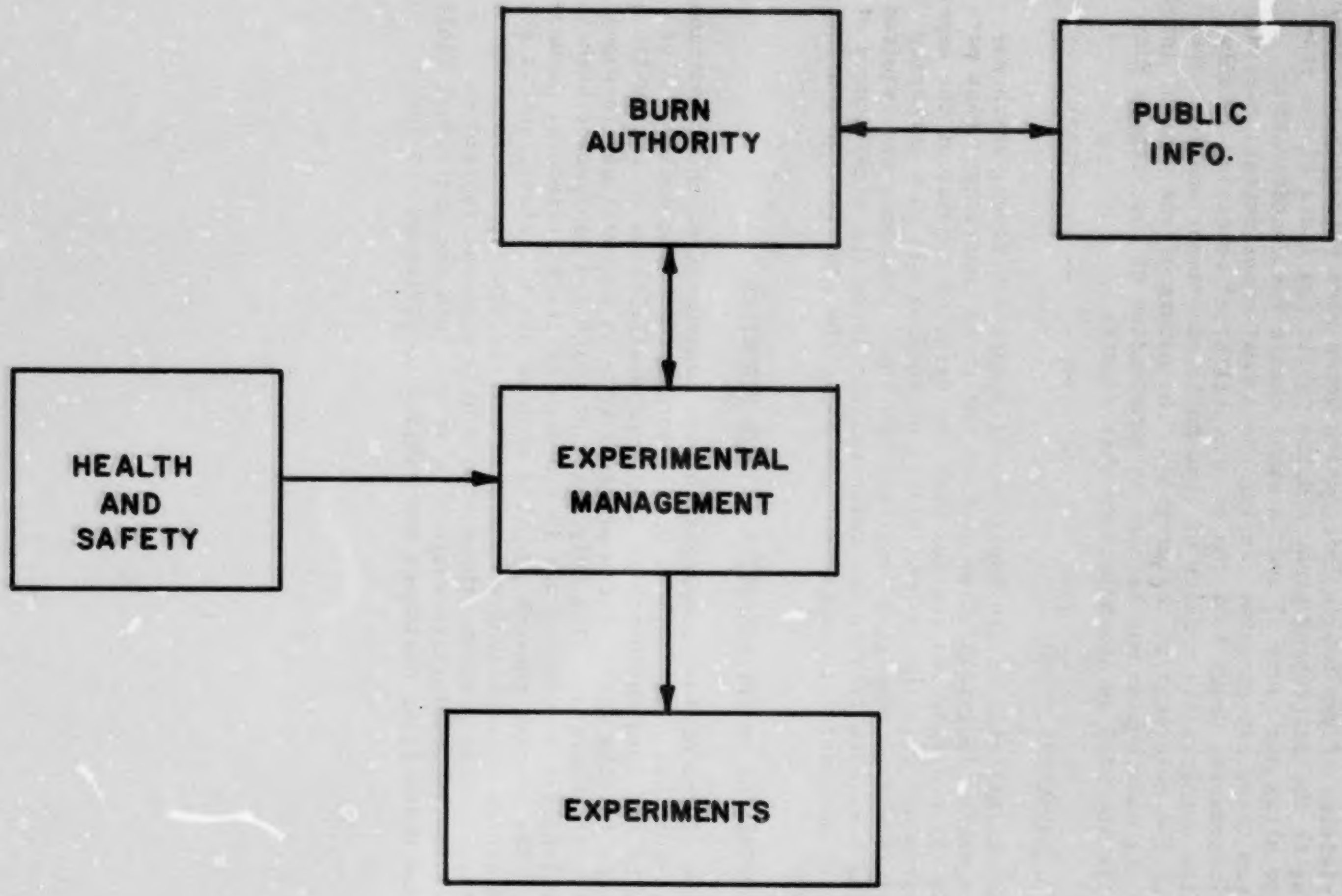
The Burn Authority consisted of the following individuals:

E.H. Bartsch, Director, Bureau of Sanitary Engineering, Department of Health, Virginia
R.A. Carnes, Environmental Scientist, Solid and Hazardous Waste Research Division, MERL, USEPA
D. Krygielski, Engineer, Toledo Pollution Control Agency
K.J. Klepitsch, Jr., Chief, Solid Waste Branch, USEPA, Region V
J. Foris, Chief, Division Technical Services, Ohio EPA

In order that the Burn Authority could properly fulfill its responsibilities with respect to the Kepone incineration test (KIT) program while at the same time to allow the members to meet their individual agency responsibilities, it was arranged that at least one member of the Authority would be in residence at all times. In addition, daily telephone communication between members of the Authority would be maintained. In those situations which might suggest that a significant alteration of the protocol was required, the entire Burn Authority was to be assembled.

Health and Safety Group

The responsibility of the Health and Safety Group began with assistance in the design of the facilities at Surface Combustion so as to provide maximum isolation of the facility. Further, this group was to provide for the personnel safety requirements during operations and the daily monitoring of personnel and facility to assure that proper hygiene was maintained and that the required protective measures were, in fact, employed. A further discussion of the health and safety measures that were undertaken and enforced is presented in Section 4 of this report. The effectiveness of these measures is treated in Section 5 and in Appendix B.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PUBLIC INFO.
HEALTH AND SAFETY
EXPERIMENTAL MANAGEMENT
EXPERIMENTS

FIGURE 1: PROGRAM MANAGEMENT STRUCTURE

Public Information

The activities of the Public Information Group were primarily directed to explaining to the interested press and the public the facts of the program so as to allay any fears of even a small chance for contamination resulting from these experiments. During the actual experimental program, the Public Information Group took the responsibility of releasing a daily bulletin which outlined the results of that day's experiment and indicated the nature of the next step in the program. The nature of the general information that was made public may be seen by examination of the "Kepone Fact Sheet" that is included as Appendix A to this report.

Experimental Management Group

The responsibilities of the Experimental Management Group, which was made up of a senior individual from each of the three contractors that participated in the program, was charged with the detailed conduct of the experimental program and with the responsibility of keeping the Burn Authority completely informed of the daily progress. Further, this body was required to assist the Burn Authority in its deliberations as to the significance of the results of each specific experiment and as to the propriety of continuing as scheduled.

GENERAL OBSERVATIONS ON THE OPERATION OF THIS STRUCTURE

In spite of the obvious complexity of the management structure outlined above, the result was, in practice, highly successful. The dedication of the members of the Burn Authority in their responsibilities to the public and their sympathy for the goals of the program, were in no small way responsible for the successful outcome. The only point at which the management structure was not particularly successful was in the area of the Experimental Management Group. The precise reasons for this problem are not clear, but it would seem that a troika of technical managers is not the most appropriate way to manage an experimental program; there should have been one individual charged with the responsibility subject to inputs from the individual field managers, and whose final decisions are subject to review by the Burn Authority.

SECTION 2

CONCLUSIONS

The results and conclusions derived from the KIT program may be summarized as follows:

(1) Coincineration of Kepone with sewage sludge is a safe and environmentally acceptable method of disposal of Kepone. The results of these experiments indicate that the destruction efficiency of Kepone is in excess of 99.9999 percent in a system consisting of a pyrolyzer, fume incinerator operating in the order of 1000°C with residence times in the order of two (2) seconds and a caustic quench/scrubber system. In no case was a detectable/Kepone level found in the pyrolyzer ash.

(2) Periodic deviations from negative pressure in the kiln permitted the escape of small quantities of Kepone to the air in the kiln room.

(3) Direct injection of low BTU solutions of Kepone would appear from these experiments not to be a useful process. This conclusion is not as firmly based as one would hope as is discussed in Section 5. Although acetic acid appears to be the best and safest available choice as a Kepone solvent, the addition of acetic acid to sludge resulted in foaming problems.

(4) Adequate safety instruction coupled with constant monitoring to assure the proper use of safety equipment is necessary to prevent the exposure of operating personnel.

(5) The planning of the facility and its isolation structures were such as to prevent the escape of Kepone into the surroundings while at the same time making it very easy to clean up the facility after the completion of the tests.

(6) Real time analyses of Kepone on the site of such a procedure is highly satisfactory and of great assistance in the decision making process.

(7) The concept of a Burn Authority made up of representatives of the responsible agencies is highly satisfactory in the control of an experiment such as the KIT program.

(8) Only a completely informed public can be cooperative at least in terms of an experiment such as the KIT program.

SECTION 3

RECOMMENDATIONS

As a result of the KIT program several recommendations may be made that will be applicable to the operations of a full scale installation for the destruction of Kepone and Kepone containing materials.

(1) The incinerator system should consist of a fume incinerator that is capable of sustained operation at temperatures of the order of 1000°C and with sufficient volume as to allow residence times of the order of two seconds; a pyrolyzer capable of sustained operation at temperatures of the order of 450°C which serves to vaporize (and probably to partially decompose) the Kepone; a strongly basic (pH above 9.0) scrubber system and a suitable air pollution control system. The entire system must be designed to operate at a significantly negative pressure and should be fitted with sensors that detect and warn when these conditions are not met.

(2) Provision should be made to allow feed of solid materials directly into sludge since the use of acetic acid, which for experimental purposes was an excellent choice, seems to introduce additional complications for large scale operations. The direct feed of low BTU solutions into the incinerator without the mediation of the pyrolyzer should be possible even though the particular combination of conditions at the experimental site seems to indicate that this is not a useful approach.

(3) The facility should have a full-time safety engineering group on its staff. The experience at Midland-Ross suggests that even though the personnel have been carefully trained in the need for and the proper use of protective equipment, they are in constant need to be reminded to use such equipment properly. In addition, the acetic acid spill that occurred during the KIT program points out the need for prompt action in the event of an accident - action that can only be properly initiated by a professional safety engineer.

(4) The incineration system that is used for the large scale destruction of Kepone and Kepone bearing materials should be separated into areas that are potentially heavily contaminated and those areas that are not subject to potential contamination. By this type of separation, the introduction of protective gear can be controlled so as to minimize the equipment needed. By such a procedure, it should be possible to minimize the time and efficiency penalties that are exacted by the use of protective equipment.

(5) The facility should provide for the retention of all liquid and solid effluent streams until analysis shows that they are not contaminated. In this context there should be a well designed sampling arrangement built into the plant which should be accompanied by a suitably designed sampling program. This sampling program should be supported by on-site analytical capability suitable for trace analysis of all samples derived from the system.

(6) A fully informed public is a requirement for the successful operation of a program of this type. Therefore, a public information program should be an integral part of the final Kepone disposal program.

(7) The KIT program was designed to determine the feasibility of incineration for the disposal of Kepone and the range of conditions that are required to affect this disposal in a safe manner. There was no serious attempt to determine the proper range of such parameters as materials that should be used, the precise geometry for a suitable incinerator system or even the performance penalties that would be exacted by the use of personnel safety equipment. Such matters were deemed to be appropriate subjects for the design studies that would follow the demonstration that Kepone could be thermally destroyed in a safe manner under thermal conditions that were reasonable.

SECTION 4

FACILITIES

It is appropriate to discuss the facilities that were involved in this program in several categories: (a) the Surface Combustion incineration facility; (b) the temporary installations that were added to the Surface Combustion facility to provide isolation of the facility and to provide for personnel safety and hygiene; (c) the facilities that were provided for the handling of Kepone and Kepone solutions; and (d) the facilities that were provided for sampling and for real time analysis of the sampled material.

SURFACE COMBUSTION EXPERIMENTAL INCINERATOR

A schematic of the layout of the experimental incinerator at Surface Combustion is shown in Figure 2. The individual components and their characteristics are discussed in the following section.

Rotary Kiln Pyrolyzer

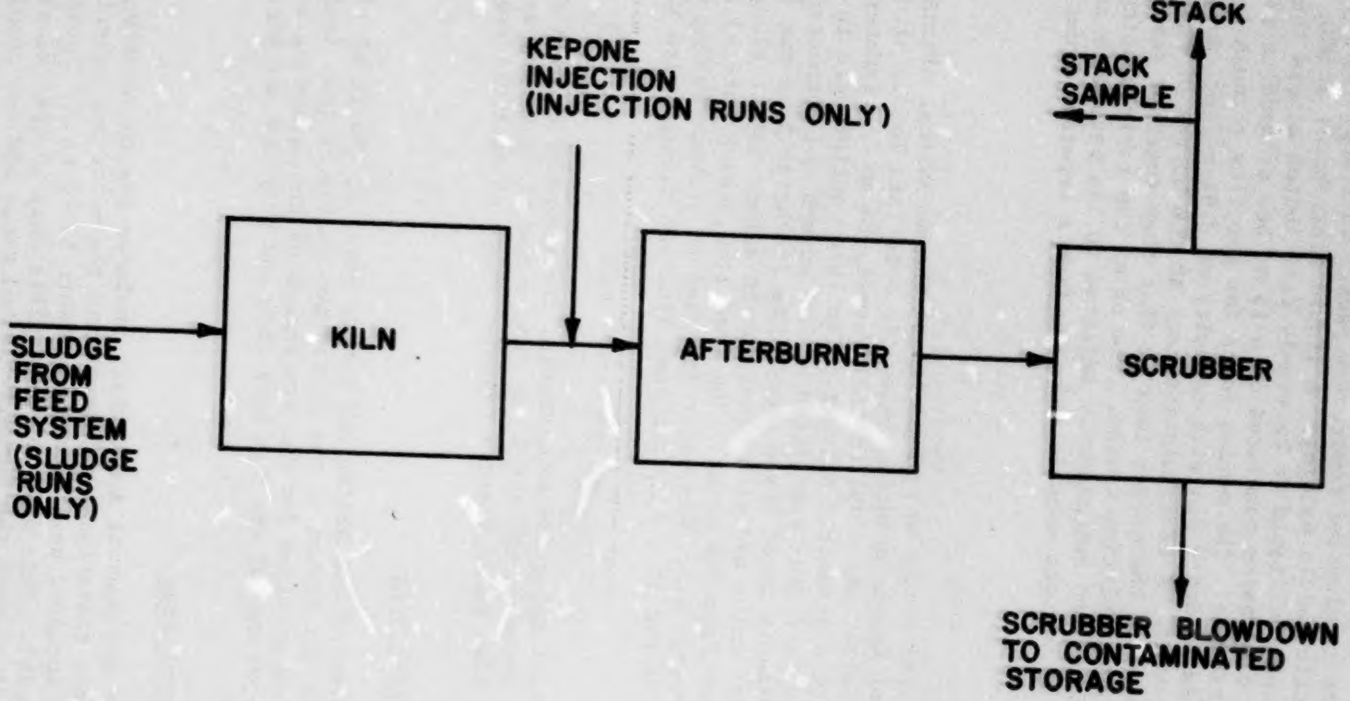
The rotary kiln pyrolyzer was 1.52 m in diameter and 3.0 m in length fitted with rotary seal charge and discharge connections so as to minimize the leakage of gases into or out of the kiln. It was heated directly by the hot gases from a 0.923 J/sec burner to maintain a nominal temperature of 500°C. Normally this kiln was batch fed through cover doors on the side, but for the purposes of the coincineration experiments the sludge feed was accomplished through a water cooled feed line which entered the kiln through the discharge pipe. The maximum feed rate was a nominal 45 kg/hr (100 lb/hr). Cake build-up within the kiln was prevented by ten rows of link chain within the kiln.

Fume Incinerator - Afterburner

The fume incinerator, with a residence chamber volume of $2.4m^3$, was fired by two 0.147 J/sec capacity throat mix burners and an auxiliary gas supply. The incinerator was equipped with a temperature controller and a high limit safety shutoff instrument. In this configuration, the maximum temperature that could be sustained was 1260°C with residence times of the order of several seconds.

Quench

The hot gases from the incinerator were cooled by evaporative cooling of the quench water that was injected at the bottom of the incinerator. The quench system, as well as the emergency cooling spray system, used water derived from the brine tank to compensate for evaporative losses with the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FEED
SYSTEM
(SLUDGE
RUNS
ONLY)
KILN
AFTERBURNER
SCRUBBER
SCRUBBER BLOWDOWN
TO CONTAMINATED
STORAGE

FIGURE 2 KEPONE INCINERATION SYSTEM SCHEMATIC

Scrubber

The scrubber, a 76 cm diameter tower, was packed to a depth of 1.83 m with 5 mm Intalox plastic saddle packing. A liquid distributor at the top of the packed bed caused the liquid to be evenly distributed across the packed bed. The mist eliminator consisted of a 15 cm bed of saddles placed above the liquid distributor. The motive force for gas flow through the entire system was an induced draft fan with capacity of 0.94 m^3/sec. mounted at the top of the scrubber. A recirculation tank at the bottom of the scrubber was interconnected with the quench tank so that they together served as a single reservoir for recirculating fluids. The pH of the recirculating water was periodically measured and subsequently adjusted to lie between 9 and 10 by the addition of a 12 percent caustic solution from a separate caustic solution reservoir.

Sludge Feed System

Kepone contaminated sludge was simulated by the mechanical mixing of appropriate amounts of Kepone solution in acetic acid into Toledo sludge in the feed tank. The latter was a cylindrical vessel, 86 cm in diameter and 60 cm high fitted with a pneumatic stirrer. The 10 cm outlet port in the conical bottom of the feed tank was fitted with a screen and connected to a two stage, size 3 variable speed Moyno pump. The discharge line was fitted with a pressure relief valve and with provision to either inject sludge from the feed tank or water from the mains. The feed line, which entered the kiln within the kiln discharge line, was water jacketed to prevent caking within the feed line. At the end of a run, the feed line was flushed with water.

Stack

During the initial injection experiments, there seemed to be a serious problem with excess water in the stack, so that a new alloy stack was installed. There was also added a stack reheater which effectively reduced stack condensation.

HEALTH AND SAFETY FACILITIES

The contributions of the Health and Safety Group to the facilities consisted largely in the design of the protective enclosure that isolated the facility and that provided for the protection of the operating personnel. The general features of the facility that was provided are shown in Figure 3.

Operations and Control Area

The Operations and Control Area, which included the incinerator, the scrubber, the furnace operational equipment and the brine and caustic storage tanks, was enclosed by a wooded framework lined on the inside with heavy plastic material. This area was accessible only to specifically authorized personnel through the normally locked doors and was considered to be minimally contaminated. Personnel that worked within this area were required to wear disposable coveralls, rubber boots and rubber gloves. On

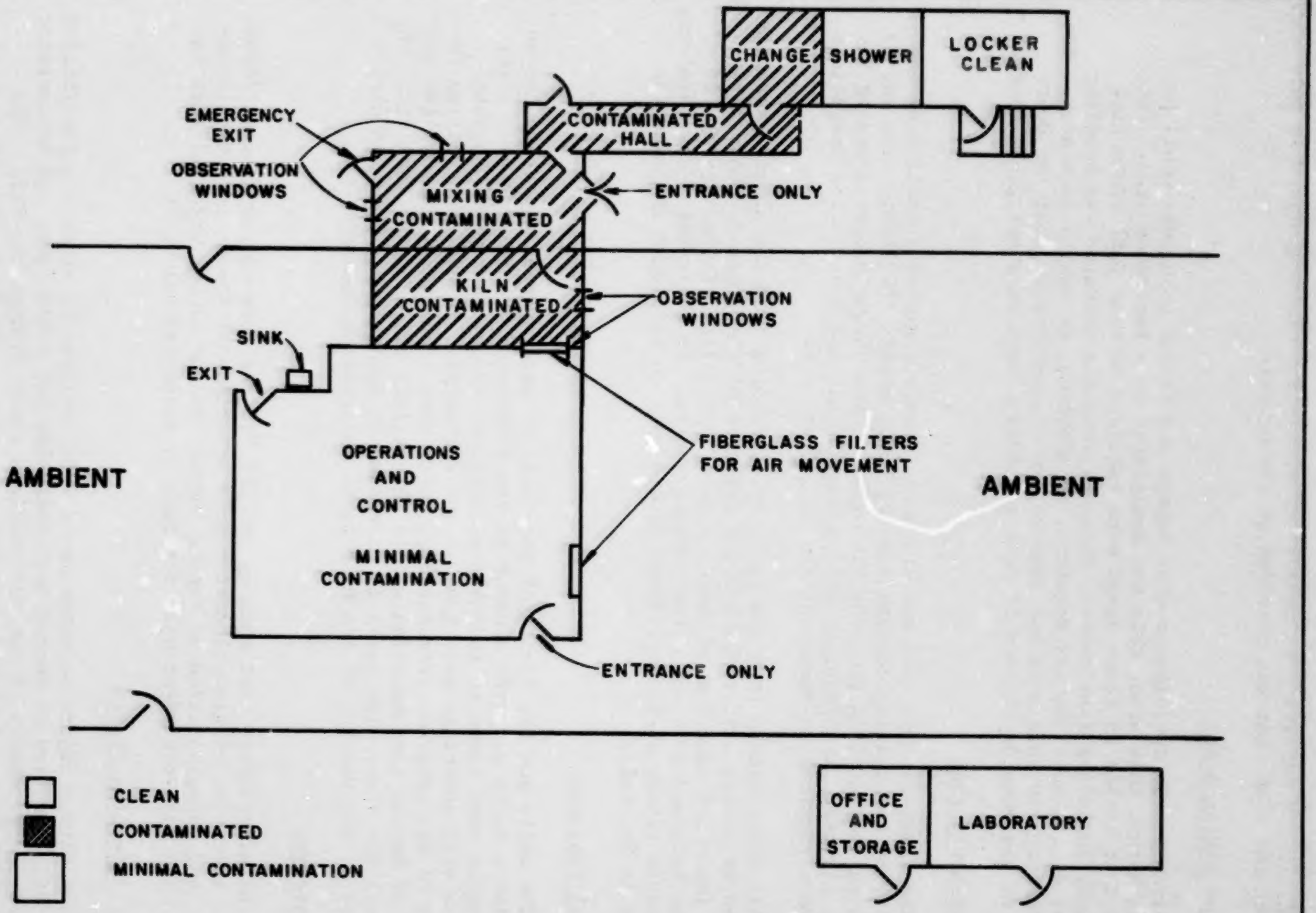

CHANGE
SHOWER
LOCKER CLEAN
CONTAMINATED HALL
EMERGENCY EXIT
OBSERVATION WINDOWS
MIXING CONTAMINATED
ENTRANCE ONLY
KILN CONTAMINATED
OBSERVATION WINDOWS
SINK
EXIT
FIBERGLASS FILTERS FOR AIR MOVEMENT
AMBIENT
OPERATIONS AND CONTROL
MINIMAL CONTAMINATION
AMBIENT
ENTRANCE ONLY
CLEAN
CONTAMINATED
MINIMAL CONTAMINATION
OFFICE AND STORAGE
LABORATORY

FIGURE 3: EXPERIMENTAL AREA- ISOLATION PLAN

leaving, it was necessary to remove the protective clothing and wash face and hands at the sink that was provided at the egress.

Kiln and Mixing Areas

Since it was anticipated that Kepone and Kepone solutions would be exposed within this area, this was designated as a hazardous area. Personnel that worked in these areas were required to wear full protective equipment including respirator. Further, when the operator was handling glacial acetic acid, he was required, in addition, to wear a face mask. The only entrance to this area was through the Change/Shower area; the doors shown to the outside (Figure 3) from the mixing room were emergency doors.

Change/Shower Area

The Change/Shower Area was provided to afford proper isolation of the facility by maintaining contaminated clothing within the change area and by making persons exiting from the Mixing/Kiln Area shower before dressing in street clothes. In addition, all personnel that had been in the Operations Room were required to shower at the end of the day.

All waste waters from the facility, including from the shower, were impounded in underground tanks fro the duration of the program. Only after these impounded waters were shown to have undetectable Kepone levels could they be released into the normal sewage system. In the event that there were detectable traces of Kepone, these waters were to be placed in drums for return to Hopewell.

General Features

The walls and the floors of the facility were specially prepared so as to allow a rapid and safe cleanup at the completion of the program. After wipe tests were shown to indicate no residual Kepone contamination, the plastic wall coverings were removed and destroyed. In addition, during the course of the program, frequent wipe tests were conducted to assure the absence of Kepone contamination within the various areas of the facility. The protocol for these wipe tests is discussed in Appendix B. There is also a summary of the results of the wipe tests included in Appendix B.

FEED SYSTEMS

The experiments that made up the KIT Program were of two general forms, direct injection of glacial acetic acid solutions of Kepone into the incinerator and coincineration of Kepone 'doped' Toledo sludge injected into the kiln. The feed equipment used for each is discussed below.

Direct Injection System

The direct injection experiments were designed to study the feasibility of direct injection of Kepone containing low BTU fluids into the incinerator without the necessity of the intermediate route through the kiln. The equipment that was designed for this purpose consisted of a set of two (2) injection nozzles and the facility necessary to mix, store and feed solutions of Kepone in glacial acetic acid.

It was decided that the injection nozzles should be placed as near to the input port of the incinerator as was physically possible in order to obviate the possibility of deposition of Kepone on the cool walls of the duct from the kiln to the incinerator. The thermal conditions that were thought to exist at the point within the duct at which the injection heads were to be introduced suggested that the small openings in a conventional spray injection head would soon be clogged. For this reason a less conventional design, shown in Figure 4, was adopted for these heads. The Kepone solution was fed through a 5mm diameter stainless tube to the head. The thermal conditions that were computed to exist within the head were such that vaporization should have occurred within the enlarged portion of the head. The heads, spaced some 30 cm apart, were directed upstream so as to increase the exposure time to assure the elimination of droplets.

The feed system that was used for the mixing, storage and feed of the glacial acetic acid solutions of Kepone is shown in the schematic diagram Figure 5 with the electrical control system diagram shown in Figure 6. It will be noted from Figure 5 that the motive force that was used for the transfer of solutions throughout the system was dry nitrogen gas. The electrical system is somewhat complex, a complexity necessitated by the requirement of interlocking the various operations so as to obviate a possible mismanagement of the highly corrosive acetic acid. The corrosive nature of the solvent also required that all the fittings in the feed system be either of aluminum, teflon or stainless steel. The physical layout of the feed system and its associated electrical control system are shown in Figure 7 which also shows the nature of the portective equipment that was required within the mixing room.

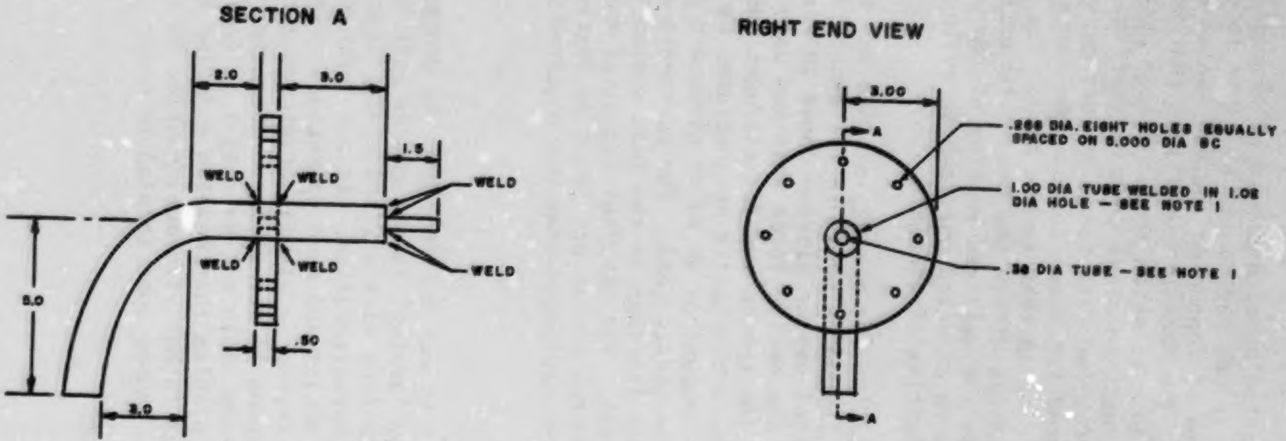
Sludge Feed System

As is indicated in Section 4 it was decided that the sludge experiments would best be conducted by 'doping' Toledo sludge with Kepone so as to generate a series of concentrations with a fixed sludge feed rate (45kg/hr) which was dictated by the kiln characteristics. It was further decided that personnel protection during the mixing and feed operations could best be obtained by mixing solutions of Kepone in glacial acetic acid into the sludge rather than by adding the dry Kepone to the sludge. There is no basis for concluding that a dry mixing system could not be used in a facility better equipped. The only significant problem that developed during these mixing operations was connected with the rather vigorous reaction of the acetic acid with the sludge, a reaction that caused some foaming to occur.

SAMPLING AND ANALYTICAL PROCEDURES

Sampling Methods

The stack gas stream was sampled at the output of the scrubber using the EPA Standard Method 5 (2) with an RAC Stacksampler (R) along two perpendicular traverses at four sampling points per traverse. The heated probe was introduced through each 7.8 cm diameter port in turn and maintained at each


SECTION A
2.0
3.0
1.5
WELD
WELD
WELD
WELD
WELD
WELD
5.0
3.0
.50
RIGHT END VIEW
3.00
A
A
.266 DIA. EIGHT HOLES EQUALLY SPACED ON 5.000 DIA BC
1.00 DIA TUBE WELDED IN 1.02 DIA HOLE — SEE NOTE 1
.38 DIA TUBE — SEE NOTE 1

NOTES:

1. MATERIAL OF 1.00 DIA. TUBE AND .38 DIA. TUBE - TYPE 304 STEEL
2. TOLERANCES:
   - 3 DEC PLACE TOL ± .005
   - 2 DEC PLACE TOL ± .010
   - 1 DEC PLACE TOL ± .10

FIGURE 4 INJECTION FEED HEAD

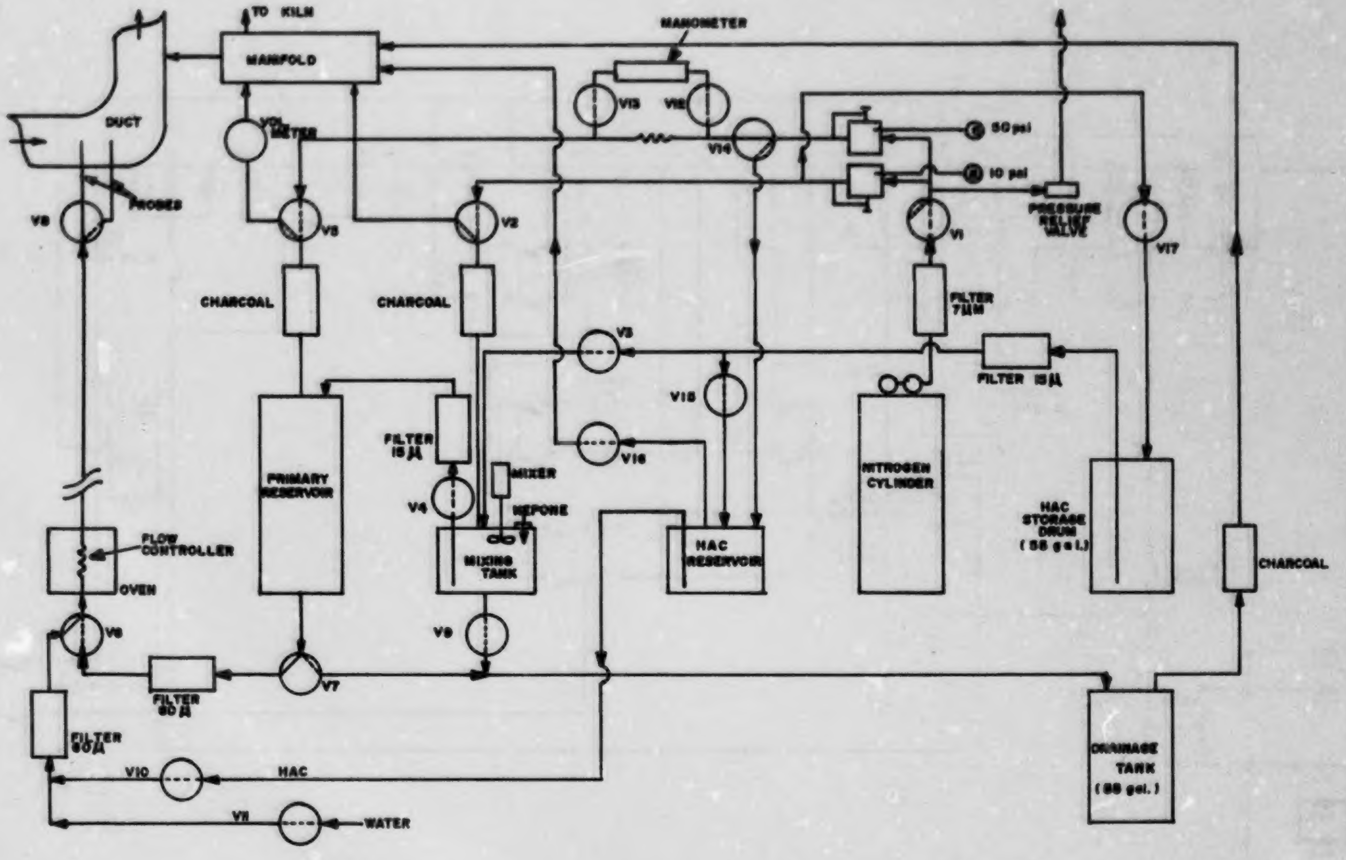

TO KILN
MANIFOLD
MANOMETER
DUCT
PROBES
V8
VOL METER
V5
V2
V13
V12
V14
50 psi
10 psi
PRESSURE RELIEF VALVE
V1
V17
CHARCOAL
CHARCOAL
V3
FILTER 7μM
FILTER 15μ
V15
V16
FILTER 15μ
MIXER
KEPONE
V4
PRIMARY RESERVOIR
MIXING TANK
HAC RESERVOIR
NITROGEN CYLINDER
HAC STORAGE DRUM (55 gal.)
CHARCOAL
FLOW CONTROLLER
OVEN
V6
V9
V7
FILTER 80 μ
FILTER 80 μ
DRAINAGE TANK (55 gal.)
V10
HAC
V11
WATER

FIGURE 5 PNEUMATIC DIAGRAM OF KEPONE INJECTION SYSTEM

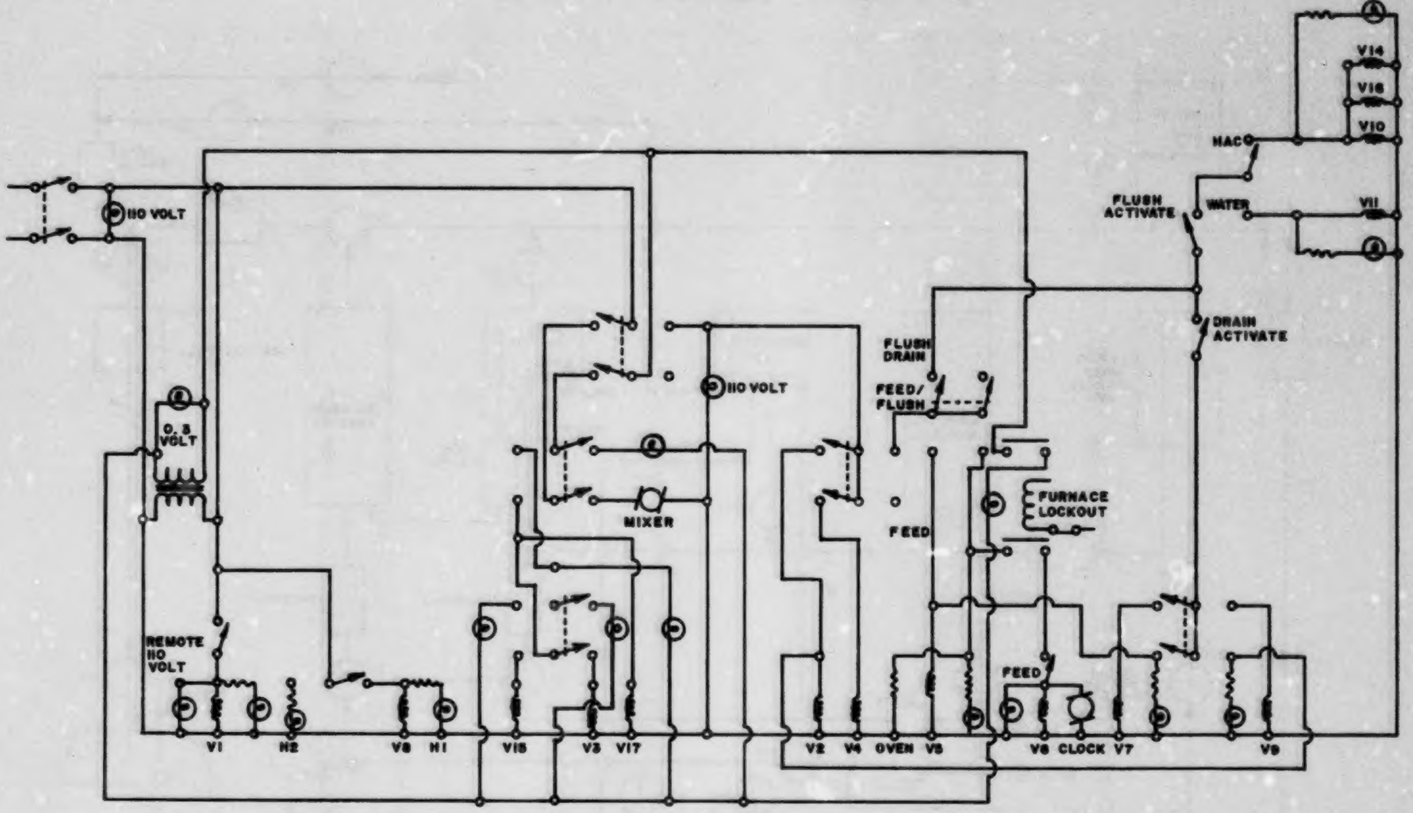
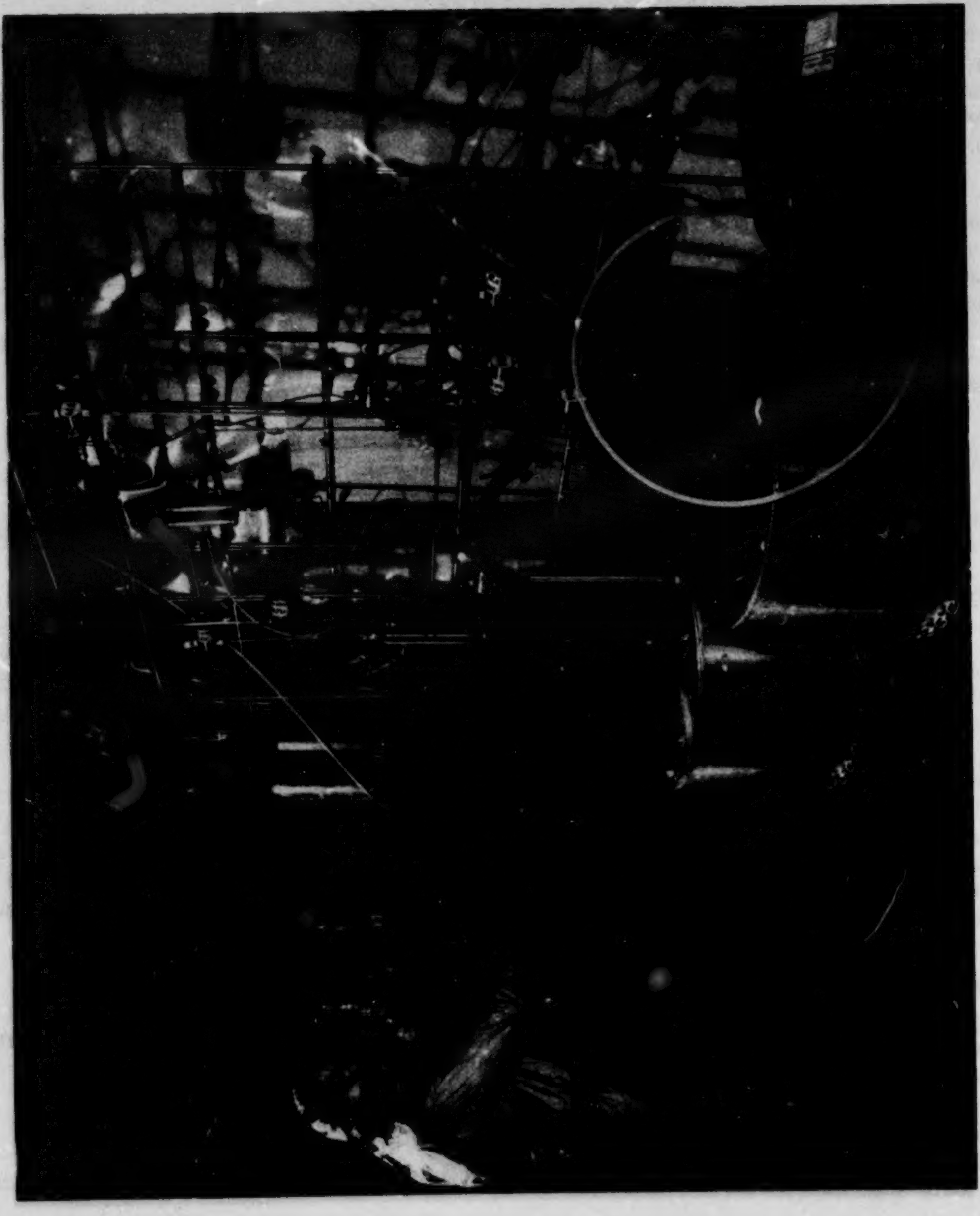

110 VOLT
0.3 VOLT
REMOTE 110 VOLT
V1
H2
V8
H1
V15
V3
V17
MIXER
110 VOLT
V2
V4
OVEN
V5
FLUSH DRAIN
FEED/ FLUSH
FEED
FURNACE LOCKOUT
FEED
V6
CLOCK
V7
V9
FLUSH ACTIVATE
DRAIN ACTIVATE
HAC
WATER
V14
V16
V10
V11

FIGURE 6 ELECTRICAL NETWORK, FEED SYSTEM CONTROL



sampling point for approximately five (5) minutes. The collected sample was passed through a 0.45 micron filter prior to its introduction into the impinger train. The first two impinger tubes of the sample train contained 100 ml of spectrograde isoctane. The entire assembly of impingers was maintained at near 0°C by use of ice and salt.

Isokinetic sampling was accomplished by first calibrating the S pitot tube against a calibrated Dwyer pitot tube using a slant gauge manometer. Minor adjustments were continuously made in the pumping speed as needed to compensate for variations in air stream velocity during a sampling run or when the probe was moved to a new sampling point.

On completion of a sampling run, the filter-cyclone assembly was removed from the heated probe box, transferred to a container and removed to the laboratory where the sample was recovered. An identical procedure was followed with the first and second impinger tube the entire assembly was removed from the sampling box, transferred to a carrying box and removed to the laboratory. This procedure was adopted to decrease the possibility of contamination but was also found to markedly increase the efficiency of handling the collected samples.

At the end of each stack sampling run, a one (1) liter sample of the scrubber water was taken. During the high level coincineration runs, further scrubber samples were taken so as to derive a profile of the changes in scrubber concentration as a function of time. Ash samples were taken at the end of each coincineration run.

Analytical Methods

The laboratory that was set up on site and the detailed equipment list are discussed in Appendix C. Suffice it to say here that the primary instrumentation that was used was a Hewlett-Packard Model 5700 series gas chromatograph with a Ni^{63} electron capture detector. The column that was normally used was a pyrex column 180 cm by 0.4 cm packed with 5% OV-210 on Gas Chrom Q, operating with the injection port at 200°C, the column temperature at 195°C and the detector port temperature at 250°C. The carrier gas used was a mixture of argon and methane (95% argon) at a flow rate of 45-50 ml/min. Quantification was made using peak area as determined by a Hewlett-Packard Model 3380 recorder-integrator. Since the identity of the Kepone was based on the retention time, numerous authentic samples were injected to assure proper identity of the Kepone peak.

G.C. retention time was found to "wander" to a greater extent than is normally observed in the laboratory. It was apparent that the extreme weather conditions that occurred during these experiments, coupled with the absence of temperature control in the laboratory (personnel frequently had to work in the laboratory fully clothed in overcoats, mufflers and gloves), caused variations in operating conditions of the gas chromatograph. The only effective control measure that could be taken was the introduction of frequent authentic samples.

Calibration

As suggested above, the extreme weather conditions at the site during these experiments made it necessary that authentic and known concentration samples of Kepone be injected on a schedule far more frequently than is normally the case. In addition, it was found necessary to check the volumetric calibration of measuring glassware by preparing spiked samples - this also made necessary because of the abnormal temperatures in the laboratory. As indicated above, the laboratory was well equipped with primary standards as well as with secondary working standards of Kepone solutions. The primary observed variation in the GC records for Kepone was a wandering of the retention time, there was no discernable effect on quantitation of the amount of Kepone present.

Quality Control Measures

Deliberate duplicates and spiked samples were introduced ad lib as part of the internal quality control program. In addition, a random number of method blanks were used with distilled water as the sample. Further, spiked filters provided by the EPA and spiked water samples provided by the Virginia Consolidated Laboratory were analyzed. Many of the ambient air filters and the high volume air monitor filters were split and sent to EPA (RTP) for confirmatory analysis. Results of these EPA (RTP) confirmatory analysis are presented in Appendix H.

Laboratory Monitoring and Interferences

As is usual, the laboratory was constantly monitored by an ambient air monitor on a continuous basis. Further, routine wipe samples were taken at weekly intervals from the floor, ceiling and laboratory benches. In addition, at frequent but irregular intervals "clean glassware" was rinsed in pesticide grade benzene, the washings concentrated and the concentrate injected into the GC, in order to determine the adequacy of the glassware washing procedures. No glassware contamination was observed by these tests. All reagents used in this program were similarily checked for possible Kepone contamination and for the presence of interferences. At no time during the experimental program was Kepone detected either in the ambient air filter or as a contaminant in clean glassware or in reagents.

Sample Handling

Because of the considerable variety of sample types that were treated in the course of this program, it is appropriate to discuss the initial sample preparation for each of the following classes of samples:

Filters and Paper Samples

In this category are included stack sample filters, ambient air filters, high volume air filters and wipe samples (made from a piece of Whatman filter paper). In the case of the first two, filters were delivered to the laboratory in a sealed holder; the wipe samples and the high volume filters were delivered in sealed envelopes. Each filter was routinely checked for moisture, color, physical change and particle deposition before being handled, without noteworthy observation. After inspection, each filter was folded into a cylindrical shape, using clean tweezers, and placed into a 30 ml glass-stoppered graduated centrifuge tube. Measured amounts of benzene (10 ml for stack gas filter and ambient air filter, 50 ml for the others) was then added to the tube, the hole stoppered and allowed to soak for 10-15 minutes. A 3 microliter aliquot of the extract was injected into the gas chromatograph. A second sample served as a check on the first.

Scrubber Samples

The one (1) liter scrubber samples were transported to the laboratory and cooled to room temperature by immersion in cold water. A homogeneous 200 ml sample was then transferred to a 500 ml erlenmeyer flask wherein the sample was acidified by the addition of 50% H_2SO_4 dropwise while stirring. The resulting solution was then transferred to a separatory funnel and extracted with three successive portion (20 ml each) of benzene. The extracts were then combined and concentrated by evaporation to 5 ml. A 3 microliter aliquot was injected into the GC for measurement.

Cyclone and Impinger Samples

After the volume of the condensed fluids in the cyclone was measured and the pH determined, the cyclone assembly was washed with several successive acetone washings. The combined washings and the collected fluids were then acidified with 6N HCl and extracted with benzene. The benzene extract, after concentration to 5 ml, was injected into the GC in the form of a 3 microliter aliquot for analysis.

The procedure followed for the impinger bottles paralleled that for the cyclone assembly, the contents of the first and second impinger being combined to form the sample.

Kiln Ash Samples

At the end of each of the coincineration experiments, a sample of the collected ash was taken for residual Kepone analysis. After the sample was thoroughly mixed, a 1.00 gram portion was weighed out. This sample was extracted with 50 ml benzene and the resulting suspension filtered through a Whatman filter. The filtrate was then concentrated to 5 ml, from which a 3 microliter aliquot was injected into the GC. If there was an indication that the sample contained Kepone the original material was then extracted on a soxhlet extractor and again chromatographed.

Additional Sample Cleanup

In some cases, particularly during the coincineration experiments, the benzene extracts were found to exhibit a large number of chromatographic peaks, thus making accurate identification of the Kepone peak difficult. In these cases an additional cleanup step was instituted. The benzene extract was dried under a gentle stream of nitrogen in a 45°C water bath. The residue was dissolved in 10 ml of 1 N NaOH followed by three successive extractions with 10 ml portions of hexane. The combined hexane extracts were concentrated to 5 ml and analyzed for degradation products of Kepone. The residual basic solution was acidified with 50% H_2SO_4 and extracted with benzene. The benzene extract was then chromatographed for Kepone. On spiked samples, this method of base-partitioning has shown Kepone recoveries of better than 90%.

SECTION 5

EXPERIMENTAL PROGRAM AND RESULTS

EXPERIMENTAL PROGRAM

The toxicity of Kepone and the nature of the publicity associated with the aftermath of the Hopewell incident made it essential that every safeguard be taken to prevent any exposure of the people of Toledo to unburned Kepone. The measures taken in this regard may be summarized here as follows:

1. The absolute imposition of an upper limit on the allowed emission, established as one microgram per cubic meter at stack conditions.
2. The careful sampling of the stack during all periods of Kepone injection into the furnace system.
3. Use of high-volume air samplers at various locations on the Midland-Ross property; these samplers to be in use during the entire experiment.
4. The entrapment and entrainment of all waters generated within the facility so that no discharge of Kepone to the environment could occur through this route.
5. Provision of essentially real time analysis of all stack samples so as to assure that the stack levels did not exceed the 1.0 $\mu gm/m^3$ limit.
6. The use of an experimental protocol designed as a series of experiments with stepwise increases in the injection rate of Kepone such that any significant approach toward the emission limit would cause the experiments to be terminated.
7. The placing of control of continuation into the next experiment in the hands of a committee of officials directly concerned with environmental protection who could, after review of each completed experiment, decide to proceed or to alter the course of the program. To proceed in an orderly manner, a detailed protocol, discussed earlier, was designed before the beginning of the experiments.

EXPERIMENTAL PROTOCOL

In order to establish a standard procedure for progressive increases in the Kepone injection rate, a definite series of experimental steps was established prior to the beginning of the test program. It was provided that the Burn Authority would have the absolute authority to determine continuation or cessation of the experimental program, and, further, it was deemed appropriate for the Burn Authority to utilize the technical staff for assistance in the decision making process, especially if it were predicted that to continue along the pre-arranged steps would lead to the emission of unacceptable levels of Kepone. The protocol outlined below was established as a guideline for an experimental program, subject to change as dictated by experimental findings as the program advanced.

Initial Program

It was considered appropriate to carry out the experimental program in two phases; (a) Direct injection of Kepone solutions into the duct leading to the afterburner so as to simulate processes associated with the destruction of technical grades of Kepone, and (b) Coincineration of Kepone in sewage sludge to simulate processes expected to be involved in the incineration of the sludge from the Hopewell Lagoon. In this spirit, the following set of experiments were planned (for completeness, the final pre-program protocol is appended as Appendix D):

Phase 1. Direct Injection Experiments

1. Kepone feed at 1.5 x 10^{-5} gm/min., 1260° C (2300°F), 2 second residence times.*
2. Kepone feed at 1.5 x 10^{-5} gm/min., 1093°C (2000°F), 2 second residence time.
3. Kepone feed at 1.5 x 10^{-2} gm/min., 1093°C (2000°F), 2 second residence time.
4. Kepone feed at 15 gm/min., 1093°C (2000°F), 2 second residence time.
5. Kepone feed at 15 gm/min, 1093°C (2000°F), 1 second residence time.
6. Kepone feed at 15 gm/min. 1038°C (1900°F), 1 second residence time.

Phase 2. Coincineration Experiments

1. Toledo sludge blank, 1093°C (2000°F), 2 second residence time.
2. Hopewell sludge at same conditions as above.
3. James River sediments at same conditions as above.**

* In all cases, the stated residence time is a nominal figure used as a lower bound on an acceptable residence time.

** Because the James River was completely frozen over, this experiment was dropped from the protocol.

4. Toledo sludge doped at 25 percent (on dry basis) with Kepone, same conditions as above.

5. Toledo sludge doped at 50 percent (on dry basis) with Kepone, same conditions as above.

Modified Program

As the direct injection experiments proceeded during the program, it became obvious from stack gas analyses that the higher injection rates planned would seriously challenge the afterburner so as to allow the stack emissions to approach or exceed the limit of 1 microgram per cubic meter, and that some alteration of the protocol was required. It was then determined that, in the interests of completing the experiments without exceeding the emission limits, it was desirable to omit the high level injection experiments and proceed to the coincineration studies.

As a result of such decisions based on the completed experiments, the actual series of experiments that were carried out consisted of the following:

Phase 1. Direct Injection Experiments

1. Acetic acid alone

2. Acetic acid solution of kepone; 1.67×10^{-5} gm/min., 1260°C (2300°F), with 2 second residence time.*

3. Acetic acid solution of kepone; 1.67×10^{-5} gm/min., 1093°C (2000°F), with 2 second residence time.

4. Acetic acid solution of kepone; 1.67×10^{-2} gm/min., 1093°C (2000°F), with 2 second residence time.

Phase 2. Coincineration Experiments

1. Toledo sludge, 1093°C (2000°F), 2 second residence time.

2. Toledo sludge with kepone, 5.68 gm/min. of kepone, 1149°C (2100°F), with 2 second residence time.

3. Toledo sludge with kepone, 5.68 gm/min. of kepone, 1093°C (2000°F), with 2 second residence time.

4. Toledo sludge with kepone, 5.68 gm/min. of kepone, 1038°C (1900°F), with 2 second residence time.

5. Toledo sludge with kepone, 24.2 gm/min. of kepone, 1093°C (2000°F), with 2 second residence time.

---

* As before, the cited residence times are to be considered as nominal values to be used as a lower bound on the actual (calculated) residence time.

EXPERIMENTAL RESULTS

The chief results of these experiments are displayed in Table 1 which summarizes the primary data derived from these tests. The detailed data on the furnace operations are presented in full in Appendix E, whereas the data derived from the stack and scrubber Kepone concentration measurements are displayed in the sections which immediately follow. In order to further simplify the following presentation, examples of typical chromatograms of authentic standards and of typical samples are displayed in Appendix F. In addition, a detailed log of the day by day events that characterized this program is presented in Appendix G.

Before proceeding with the presentation of the detailed data it is appropriate to indicate several results of a general nature that derive from these experiments. First, the interaction of the Burn Authority with the Experimental Management Group was continuous and of great benefit to the overall program. Evidently, this form of program management is a viable and useful tool to be exploited in all such experiments with hazardous materials.

There has been some question raised about the effect of the personnel safety measures on the productivity of the operating personnel. Although this was not considered to be an experimental variable, the reduction in productivity did have a major impact on the program costs. Specifically, the day-by-day wearing of protective equipment in the Operations Room and the personal hygiene regimen imposed on those workers, appears to have resulted in a 15 to 20 percent increase in costs of these day-by-day operations. It would also appear that the necessity of the full protection, including the respirator, resulted in a 50 percent decrease in productivity (this is only an estimate). Further, the expenditure of some 10 hours per person in the lecture portion of the safety program, had a significant impact on the total manpower hours that were expended, especially in terms of a program limited to some eight weeks.

Stack Sampling Data

The stack samples were collected in accordance with EPA Method Five using the RAC Staksampler (R). The data for the twenty eight (28) separate stack sampling runs are summarized in Table 2 and 3 which follow. The derived quantities were calculated in accordance with the procedures outlined in ASTM Method D2929. The corresponding Kepone concentrations found for these stack runs are tabulated in Tables 4 and 5. It will be noted that at no time did the stack emission rate exceed the pre-established level of 1×10^{-6} gm/m^3 at stack conditions.

Scrubber Data

The scrubber samples were, in the earlier experiments, taken at the end of each stack sample run. Unfortunately, it was discovered that the position from which such samples were taken was the reservoir for the scrubber system and thus the concentration measurements were of little significance. In addition, it was found that the average level of water in the scrubber system

TABLE 1: SUMMARY OF KEPONE INCINERATION EXPERIMENTS

Experiments	Kepone Feed Rate (gms/min)	Total Feed Time (min)	Total Kepone Fed (gms)	Stack Emission Concentration (gm/m^3)	Total Stack Output (gms)	After-burner Temp (°C)	After-burner Temp (°F)	Key for Scrubber Samples	Key for Stack Scans
Injection Runs									
1	Acetic Acid Only					1260	2300	1	1
2	1.67×10^{-5}	130	2.16×10^{-3}	ND	ND	1260	2300	2,3	2,3
3	1.67×10^{-5}	135	2.25×10^{-3}	ND	ND	1093	2000	4-6	4,5,6
4	1.67×10^{-2}	100	1.67	ND*	ND*	1093	2000	7,8	7,8
5	1.50	115	172.5	5.35×10^{-8}	1.76×10^{-4}	1093	2000	9-11	9,10,11
Sludge Runs									
6**	Background	120	–	2.96×10^{-7}	7.1×10^{-4}	1093	2000	12	12
7	Toledo Sludge Only	120	–	ND	ND	1093	2000	13,14	13,14
8	5.68	315	1789	1.7×10^{-8}	1.85×10^{-4}	1149	2100	16-22	16-19
9	5.68	240	1354	2.4×10^{-8}	1.85×10^{-4}	1093	2000	23-31	20-22
10	5.68	220	1241	2.55×10^{-8}	1.53×10^{-4}	1038	1900	32-40	23-25
11	24.2	165	3995	2.95×10^{-8}	1.67×10^{-4}	1093	2000	41-46	26-28
Totals			8553 gms		1.58×10^{-3} gms				

* Apparent kepone peak on chromatogram of filter collected. The kepone peak did not appear after base partitioning of original extract.

** Experiment 6 was run with a highly contaminated scrubber water (25 ppb of kepone) in an attempt to find the causes of the high emission in the previous experiment.

See Tables 4, 5, & 6

See Tables 2 & 3

TABLE 2 Summary of Stack Sampling Data

Run No.	Pmeter	Impinger Temp.	Sample Volume	Water Collected	Total Sample	Percent Water	Sample Time	Water Loss
	(mm Hg)	(^oK)	(m^3)	(ml)	(m^3)		(min.)	(gm/sec)
2	678	300	1.138	100	1.267	15	48	32.8
3	579	300	1.169	100	1.316	17	45	31.5
4	599	303	0.537	145	0.768	36	31	84.5
5	617	290.5	0.993	105	1.171	41	48	38.5
6	597	291.6	0.933	100	1.113	18	48	13.2
7	478	301	0.663	460	1.645	62	42	125
8	511	298	0.780	429	1.619	55	42	119
9	538	306	0.477	400	1.188	64	40	117
10	544	300	0.662	412	1.418	57	40	105
11	627	296	0.681	91	0.798	21	41	36
12	572	306	0.637	380	1.290	56	35	119
13	645	300	0.817	170	1.102	27	39	70
14	533	263	0.741	444	1.580	56	39	135
15	---	---	Aborted	---	-----	--	--	---
16	572	305	0.676	349	1.277	52	34	123
17	544	298	0.713	377	1.376	54	32	126
18	551	301	0.706	226	1.111	41	32	94
19	480	310	0.665	202	1.060	46	32	90
20	478	313	0.648	215	1.070	49	32	88
21	572	314	0.630	246	1.029	49	29	102
22	658	305	0.447	165	0.688	41	25	98
23	470	311	0.648	185	1.015	47	32	87
24	467	305	0.545	170	0.897	46	29	85
25	460	301	0.651	260	1.170	52	30	107
26	584	301	0.688	143	0.954	29	32	72
27	587	297	0.655	156	0.921	32	30	78
28	634	302	0.527	163	0.774	37	26	102

TABLE 3 Summary of Stack Velocity Data

Run No.	% Water	Sp. Gr. Stack Gas	T_s	$(\sqrt{h})$ ave	v ave	Q_v
			(^oK)		(m/sec)	(SCMH x 10^{-3})
2	15	0.815	362	0.397	8.43	1.52
3	17	0.794	361	0.383	8.23	1.48
4	36	0.869	361	0.438	8.99	1.62
5	41	0.852	352	0.430	8.82	1.62
6	18	0.932	358	0.358	7.07	1.30
7	62	0.780	355	0.410	8.83	1.61
8	55	0.803	355	0.417	8.84	1.61
9	65	0.773	355	0.318	6.89	1.26
10	57	0.797	355	0.335	7.13	1.31
11	21	0.921	355	0.314	6.22	1.14
12	56	0.800	351	0.374	7.89	1.46
13	27	0.900	386	0.465	9.70	1.63
14	56	0.800	390	0.468	10.42	1.73
15	--	-----	Aborted	-----	----	----
16	52	0.814	405	0.449	10.09	1.62
17	54	0.809	408	0.461	10.44	1.66
18	41	0.852	408	0.473	10.43	1.66
19	46	0.835	405	0.478	10.61	1.70
20	49	0.825	411	0.446	10.03	1.59
21	49	0.825	411	0.432	9.71	1.54
22	41	0.852	422	0.424	9.51	1.46
23	47	0.831	405	0.484	10.77	1.72
24	46	0.836	405	0.450	9.99	1.60
25	52	0.816	405	0.484	10.87	1.74
26	29	0.894	405	0.503	10.80	1.73
27	32	0.883	405	0.477	10.30	1.65
28	37	0.866	405	0.496	10.81	1.73

T_s = Stack Temperature (^oK)

h = Velocity Pressure $(\text{mmH}_2\text{O})^{1/2}$

v = Stack Gas Velocity (m/sec)

Q_v = Stack Gas Flow Rate (Standard m^3/hour)

TABLE 4 Stack Kepone Concentration Data
for Injection Experiments

Sample	Kepone Detected (gms)	Sample Vol. (SCM)**	Kepone Conc. (gm/M^3)	Kepone Emmission Rate (gm/min.)
2	ND	1.267	0	0
3	ND	1.316	0	0
4	ND	0.768	0	0
5	ND	1.171	0	0
6	ND	1.113	0	0
7	ND*	1.645	0	0
8	ND	1.619	0	0
9	ND	1.188	0	0
10	90×10^{-9}	1.418	63×10^{-9}	13.8×10^{-7}
11	17×10^{-9}	0.798	21×10^{-9}	4.0×10^{-7}
12	296×10^{-9}	1.290	229×10^{-9}	55.7×10^{-7}
13	ND	1.102	0	0
14	ND	1.580	0	0
15	ABORTED			

*A peak appeared in the original extract of the cyclone sample which disappeared after base partitioning of the extract.

**SCM = Standard Cubic Meters at 21.1°C (70°F) and 760 mm Hg pressure.

TABLE 5 Stack Kepone Concentration Data for Coincineration Experiments

Sample Run	Kepone Detected (gms)	Sample Volume (SCM)**	Kepone Conc (gm/M^3)	Kepone Emission Rate (gm/min)
16	ND		--	--
17	ND		--	--
18	10×10^{-9}	1.11	9×10^{-9}	2.5×10^{-7}
19	43.9×10^{-9}	1.06	41.4×10^{-9}	11.7×10^{-7}
20	40×10^{-9}	1.07	37.4×10^{-9}	9.9×10^{-7}
21	30×10^{-9}	1.03	29×10^{-9}	7.4×10^{-7}
22	28×10^{-9}	0.688	40.7×10^{-9}	9.9×10^{-7}
23	37×10^{-9}	1.015	36×10^{-9}	10×10^{-7}
24	22×10^{-9}	0.897	24.5×10^{-9}	6.5×10^{-7}
25	34×10^{-9}	1.17	29.1×10^{-9}	8.4×10^{-7}
26	31.2×10^{-9}	0.954	32.7×10^{-9}	9.4×10^{-7}
27	31.3×10^{-9}	0.021	34.0×10^{-9}	9.4×10^{-7}
28	27×10^{-9}	0.774	34.9×10^{-9}	10×10^{-7}

*SCM = Standard Cubic Meters at 21.1°C (70°F) and 760 mm Hg pressure.

was not recorded during the earlier runs so that there was no way to determine the total level of Kepone within the scrubber system. These deficiencies were corrected so that scrubber samples 16 through 46 were taken at the appropriate site within the scrubber system and the level of water within the system was recorded so that total quantities of Kepone within the scrubber/quench system could be determined. The results of the analyses of the scrubber concentrations are tabulated in Table 6.

The data that are presented in Column 5 of Table 6 were derived under the assumption that when the scrubber reservoir had a level of 1.57 m the total volume of the scrubber/quench system was 1325 l and that a 2.54 cm change in this level corresponded to a 16.7 l change in volume. With this basis it was possible to convert the measured concentrations of Kepone within the scrubber (Column 2 - Table 6) into total scrubber kepone loads.

ANALYSIS OF EXPERIMENTAL RESULTS

Efficiency of Combustion

The results from the direct injection experiments are displayed in Table 7 and those for the coincineration experiments in Table 8. The reported efficiencies all of which exceed 99.99 percent which are based on the stack emission rate divided by the Kepone input rate, strongly support the conclusion that incineration is a viable and safe method of disposal of Kepone and of Kepone contaminated sludges at least under the conditions that the afterburner temperature is not less that 1038^{o}C (1900^{o}F) and the residence time is of the order of two (2) seconds.

The relatively high levels of Kepone detected in the stack during the 1.5 gm/min. injection run suggested that further tests with even higher injection rates could lead to unacceptable Kepone emission rates; as a result, such experiments were discontinued in favor of the coincineration studies. The results of the highest level injection run were complicated by the absence of any useful method of determining whether passage of Kepone through the afterburner was due to inadequate vaporization within the injection nozzle (which was of unconventional design), or to some transient change in afterburner conditions, or did, in fact, represent an accurate measure of the capabilities of the afterburner. The internal consistence of the discussion presented in Section 7.3 does, however, suggest that the measured efficiency from the injection experiments are entirely consistent with those from the coincineration experiments.

The high Kepone emission rates that were observed during runs 12-14, which occurred with no Kepone feed into the system but with relatively heavily contaminated scrubber water (25 ppb), cannot be readily explained, especially in view of the fact that during the last of the coincineration experiments the scrubber concentration rose to even higher levels. It is perhaps relevant to point out that the measured stack water content was also

TABLE 6 Scrubber Sample Data

Sample No.#	Measured Kepone Concentration	Time Taken	Scrubber Volume**	Scrubber Kepone Load	Kepone Feed	AB Temp.
	(ppb)	(min)*	(M^3)	(gms)	(gms/min)	(°C)
16	0	(Background)		0		1149
17	0.74	105	1.14	8.4×10^{-4}	5.68	(2100°F)
18	3.0	155	1.108	3.33×10^{-3}		
19	3.1	185	1.242	3.80×10^{-3}		
20	3.1	230	1.292	4.00×10^{-3}		
21	6.6	260	1.058	6.99×10^{-3}		
22	5.2	290	1.225	6.37×10^{-3}		
23	8.3	(Background)				1093
24	6.7	30	1.175	7.87×10^{-3}	5.68	(2000°F)
25	5.5	60	1.004	5.52×10^{-3}		
26	5.2	90	0.842	4.38×10^{-3}		
27	4.8	125	1.067	5.12×10^{-3}		
28	4.8	150	0.900	4.32×10^{-3}		
29	5.19	180	1.125	5.84×10^{-3}		
30	13.7	210	0.933	1.28×10^{-2}		
31	11.8	240	1.241	1.47×10^{-2}		
32	9.6	(Background)				1038
33	11.9	10	1.183	1.41×10^{-2}	5.68	(1900°F)
34	15.0	40	0.996	1.45×10^{-2}		
35	10.9	70	1.376*	1.50×10^{-2}		
36	14.1	100	1.125*	1.59×10^{-2}		
37	13.7	130	1.283	1.76×10^{-2}		
38	17.2	160	1.067	1.84×10^{-2}		
39	15.1	180	1.195	1.80×10^{-2}		
40	13.3	205	1.050	1.40×10^{-2}		
41	29	(Background)				1093
42	31.7	18	1.083	3.43×10^{-2}	24.2	(2000°F)
43	27	48	0.879	2.37×10^{-2}		
44	32.4	78	1.100	3.56×10^{-2}		
45	25.9	108	0.908	2.35×10^{-2}		
46	18.1	138	1.133	2.05×10^{-2}		

# Scrubber sampling during the first set of experiments was deemed to be of no value since there was no measure available for the volume of the (closed) scrubber system at the time of sampling. Thus the data for samples 1-15 are not included in this summary.

* Measured from onset of Kepone feed.

** Calculated from scrubber water level data, based on average filled scrubber volume of 1325 L (350 gal).

TABLE 7 Combustion Efficiency for Kepone Injection

Stack Sample	Kepone Feed Rate (gm/min)	After-burner Temp (°C)	Stack Kepone Loss (gm/min)	Efficiency of Combustion %
2	1.67×10^{-5}	1260	0	100*
3	1.67×10^{-5}	1260	0	100
4	1.67×10^{-5}	1093	0	100
5	1.67×10^{-5}	1093	0	100
6	1.67×10^{-5}	1093	0	100
7	1.67×10^{-2}	1093	0	100
8	1.67×10^{-2}	1093	0	100
9	1.50	1093	0	100
10	1.50	1093	0	100
11	1.50	1093	13.8×10^{-7}	99.99991
12	0	1093	4.0×10^{-7}	**
13	0	1093	55.7×10^{-7}	**
14	0	1093	0	--
15	0	1093	0	--

* To speak of 100 percent combustion efficiency is somewhat unrealistic but is a natural consequence of the definition for efficiency of combustion in those situations for which there is so small a stack load of Kepone that it was undetectable. Further, the expression of the combustion efficiency in terms of 6 or 7 decimal places is justified since even if both the input rate and the emission rate were in error by as much as 25 percent, the extremes would only affect the combustion efficiency in the sixth decimal place -- again a consequence of the definition of the combustion efficiency and the very small emission rates that were found.

** Stack samples 12, 13 and 14 were taken during experiments 6 and 7 (see Table 1-1 for details). The scrubber was contaminated so that even in the absence of Kepone feed there was detectable Kepone in the stack.

TABLE 8 Coincineration Efficiency for Kepone with Sewage Sludge

Stack Sample	Kepone Feed Rate (gm/min)	Afterburner Temp (°C)	Stack Kepone Loss (gm/min)	Efficiency of Destruction * (%)
16	5.68	1149	0	100
17	5.68	1149	0	100
18	5.68	1149	2.5×10^{-7}	99.99995
19	5.68	1149	11.7×10^{-7}	99.99998
20	5.68	1093	9.9×10^{-7}	99.99998
21	5.68	1093	7.4×10^{-7}	99.99998
22	5.68	1093	9.9×10^{-7}	99.99998
23	5.68	1038	10×10^{-7}	99.99998
24	5.68	1038	6.5×10^{-7}	99.99999
25	5.68	1038	8.4×10^{-7}	99.99998
26	24.2	1093	9.4×10^{-7}	99.999996
27	24.2	1093	9.4×10^{-7}	99.999996
28	24.2	1093	10×10^{-7}	99.999996

* See footnote Table 7.

highly variable during this run and also that the pH of the water collected in the stack sample also varied from neutral to highly basic (the larger the collected volume the more likely it was to be basic). Further, the ambient weather conditions that prevailed during the early set of measurements (runs 1 through 14) when the average temperature was well below 0^{o}C, had the effect of causing the stack plume to appear to arise from well within the stack itself. In the interval between the first set of runs and the last series which involved coincineration (16-28), a new stack and a stack reheater were installed. The modified stack coupled with the considerable amelioration in the weather probably affected the observed results.

Scrubber Kepone Concentration and Kepone Load

During the coincineration experiments it was decided that frequent scrubber samples should be taken in order to understand better the effects that the scrubber had on the apparent Kepone destruction ratio of the total system. The scrubber Kepone load at any instant was found by multiplying the concentration at that moment by the instantaneous volume of the scrubber using the conversion factors that are discussed in Section 6.2. The results of such measurements and calculations are displayed in Table 6 (Column 5) and more graphically in Figures 8 through 11.

A study of the Figures 8 through 11 indicates that the time rate of change of the total scrubber Kepone load is quite different in each case and further, that there are very striking differences in the nature of the observed changes. The data in each plot are summarized by the least squares fit to an equation of the form

$$m(t) = m(0) + b(t) \qquad (7.1)$$

where m(t) is the total Kepone mass in the scrubber at time t
m(0) is the initial Kepone mass in the scrubber at time t=0
b is a constant that characterizes each set of conditions
t is the elapsed time
[note also that the constant b is the slope of the plot of m (t) vs. t]

In order to attempt an understanding of the significance of the curves presented in Figure 8 through 11, it is useful to summarize the data on stack emission rates from Table 5, with the slopes of the curves in Figures 8 through 11, in Table 9. It is first of all important to note that the stack emmission rates (Column 2, Table 9) are, in all cases, on the order of one percent of the rate o change of the scrubber Kepone load (Column 3, Table 9). With this observation, we may assume that the rate of loss of from the scrubber due to evaporative losses up the stack is only a small effect and thus may be neglected in what follows.

Now, the rate of change of Kepone mass within the scrubber is necessarily the result of the interaction of several phenomena; that is to say, was injected into the scrubber from the unburned material that traversed the incinerator. One would expect, in view of the smallness of the rate of stack emission, that the slopes of the curves in Figure 8 through

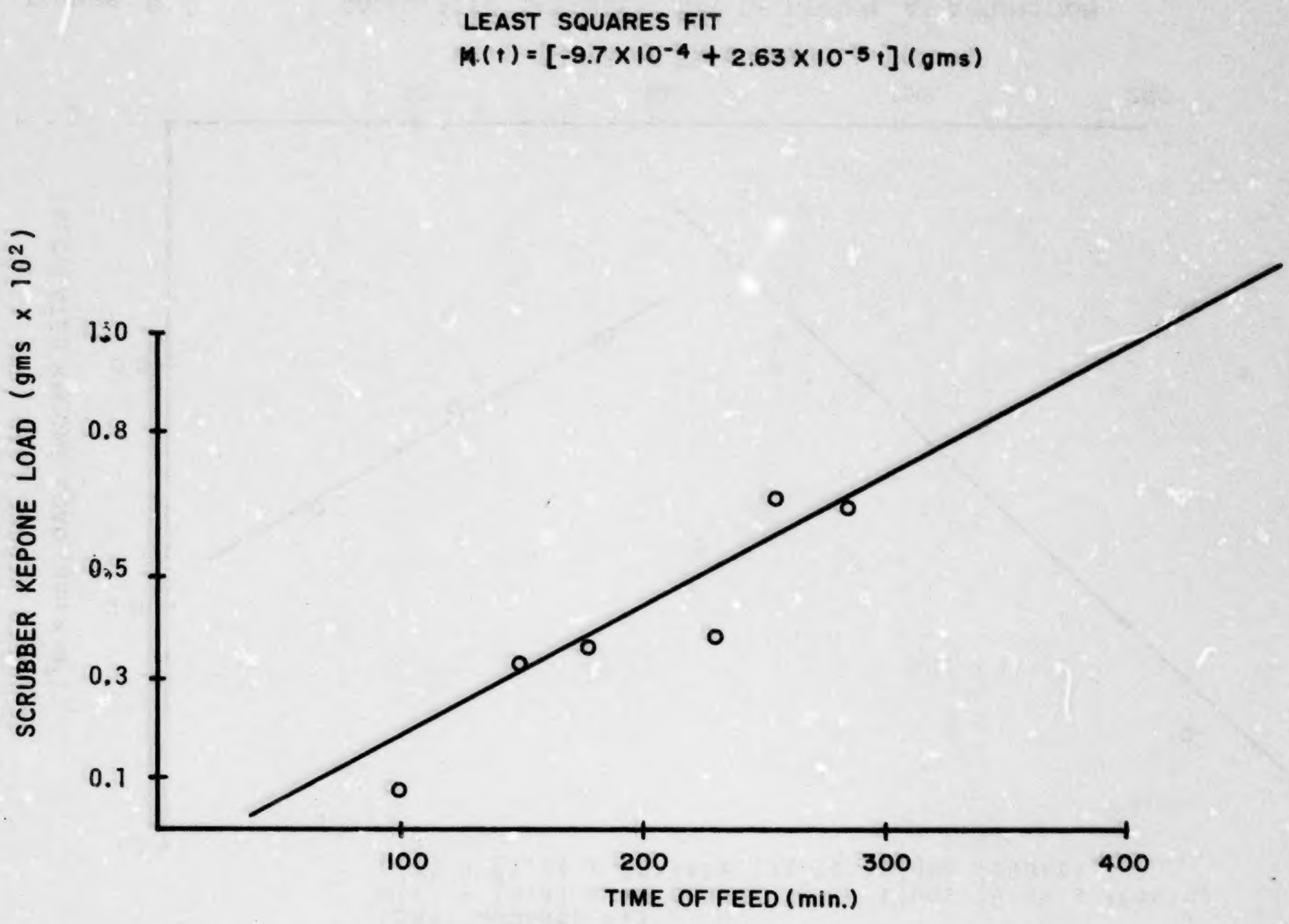


FIGURE 8 : CALCULATED SCRUBBER LOAD OF KEPONE AS A FUNCTION OF TIME (5.64 gm/min. KEPONE FEED; AB TEMP. 1149°C (2100°F)

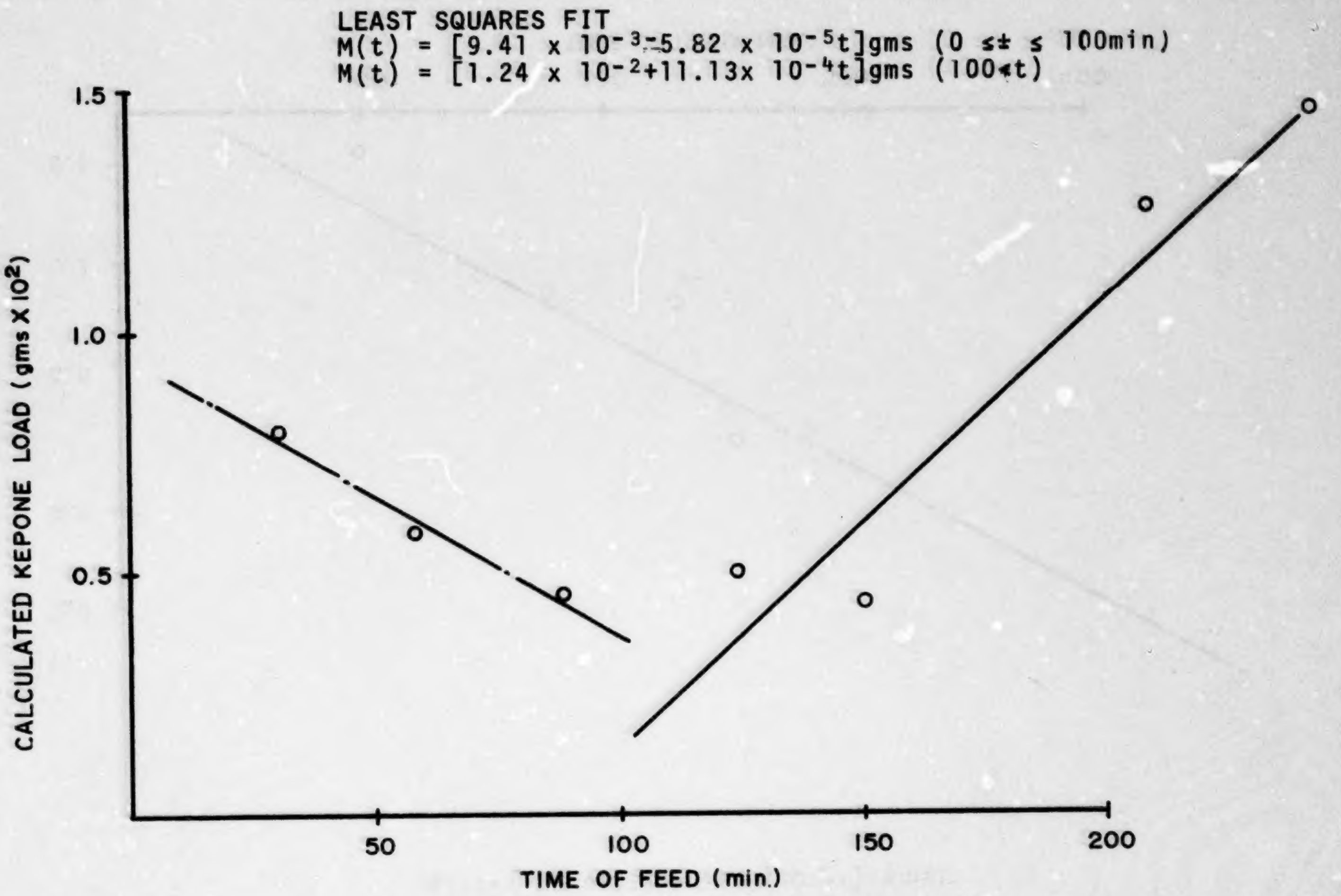
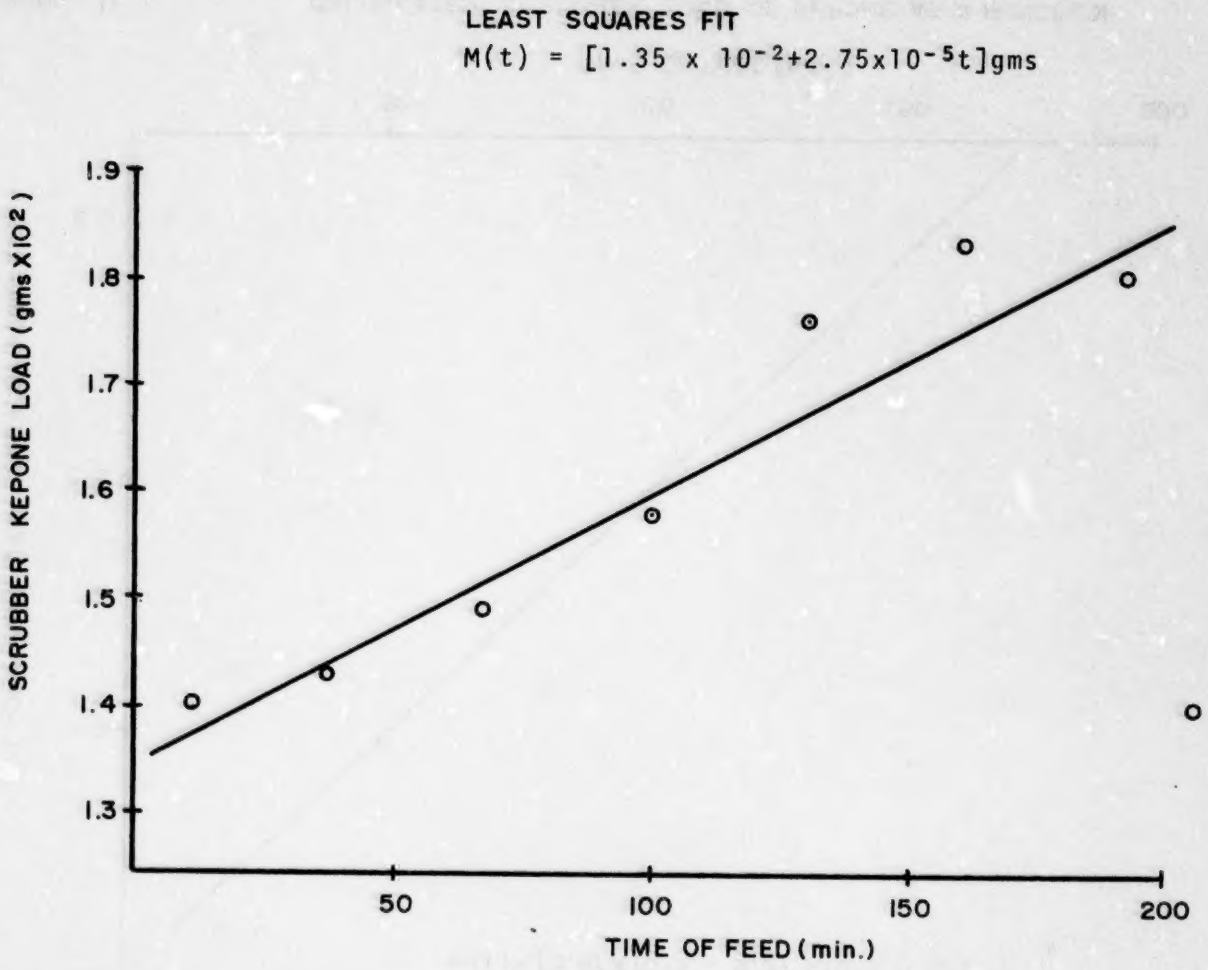


FIGURE 9: CALCULATED SCRUBBER LOAD OF KEPONE AS A FUNCTION OF TIME [5.64 gm / min. KEPONE FEED; AB TEMP. 1093°C (2000°F)]


LEAST SQUARES FIT

$M(t) = [1.35 \times 10^{-2} + 2.75 \times 10^{-5} t]$ gms

FIGURE 10 : CALCULATED SCRUBBER LOAD OF KEPONE AS A FUNCTION OF TIME 5.64 gm/min. KEPONE FEED; AB TEMP. 1038°C (1900°F)

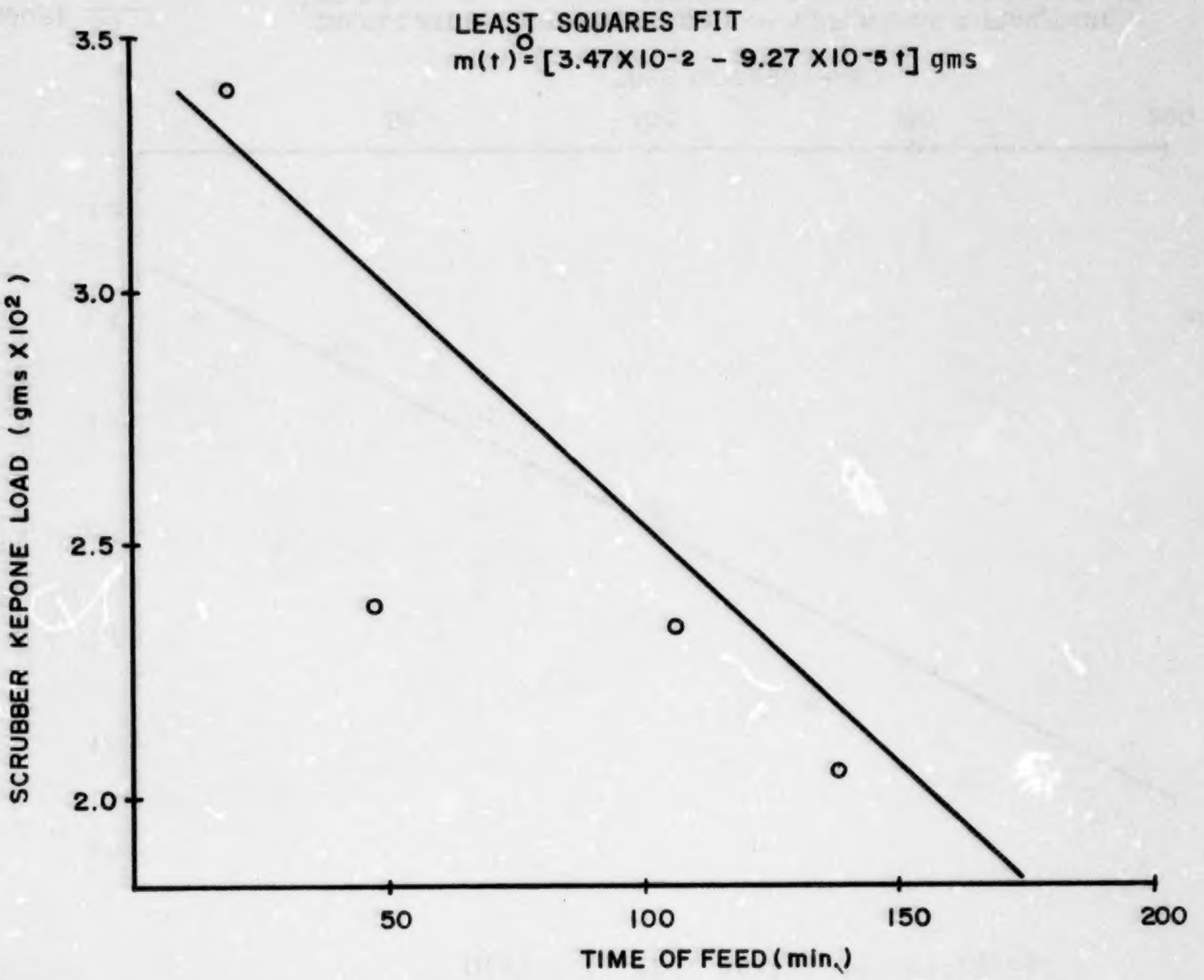


FIGURE 11: CALCULATED SCRUBBER LOAD OF KEPONE AS A FUNCTION OF TIME 24.2 gm/min. KEPONE FEED; AB TEMP. 1093°C (2000°F)

TABLE 9 Tabulation of Kepone Input and Loss Rates (Scrubber)

Stack Sample	Stack Kepone Loss (gm/min.)	Slope of Scrubber Load (gm/min.)	Scrubber Kepone Input Rate (gm/min.)
16	0	2.63×10^{-5}	11.9×10^{-5}
17	0	2.63×10^{-5}	11.9×10^{-5}
18	2.5×10^{-7}	2.63×10^{-5}	11.9×10^{-5}
19	11.7×10^{-7}	2.63×10^{-5}	11.9×10^{-5}
20	9.9×10^{-7}	-5.82×10^{-5}	12.0×10^{-5}
21	7.4×10^{-7}	9.64×10^{-5}	12.0×10^{-5}
22	9.9×10^{-7}	9.64×10^{-5}	12.0×10^{-5}
23	10×10^{-7}	2.75×10^{-5}	18.9×10^{-5}
24	6.5×10^{-7}	2.75×10^{-5}	18.9×10^{-5}
25	8.4×10^{-7}	2.75×10^{-5}	18.9×10^{-5}
26	9.4×10^{-7}	-9.27×10^{-5}	0
27	9.4×10^{-7}	-9.27×10^{-5}	0
28	10×10^{-7}	-9.27×10^{-5}	0

11 would all be positive; that is one would expect the scrubber load to continually increase with time. That is clearly not the case, as for example in Figure 11. It then becomes necessary to assume that there are processes that operate within the scrubber to decrease the amount of **Kepone** that is present; that is to say, there must be processes that are operative within the scrubber that can destroy Kepone.*

In general, the amount of kepone that passes through the incinerator for a given rate of input to the kiln must necessarily depend on the Kepone feed rate and on the thermal conditions that occur within the afterburner and in the kiln. Suppose that, for the sake of argument, it is assumed that the particular conditions that existed during the run from which the data displayed in Figure 11 were obtained, were such as to reduce the rate of Kepone injection into the scrubber to zero. Under these circumstances, the behavior of the scrubber during that experiment was governed only by those destructive processes particular to the scrubber itself. From this observation, we may estimate that those processes operate to destroy kepone at the rate

$$dm/dt = 9.27 \times 10^{-5} \text{ gm/min} \qquad (7.2)$$

as obtained from the slope of Figure 11.

If it is now assumed that these processes are always operative independent of the conditions that occur within the kiln or the afterburner, then the results shown in Equation (7.2) may be used in conjunction with the observed slopes in Figures 8 through 10, to compute the rate at which Kepone must have been injected into the scrubber in those experiments. The results of these calculations are displayed in Column 4 of Table 9.

With the data that are displayed in Table 9 and those in Table 1 (for the Kepone injection rate from Column 2 of Table 1) it is possible to compute the effective efficiency of the incinerator - kiln plus afterburner - independently of the scrubber effects. The results of this calculation are displayed in Table 10.

To carry this discussion one step further, it will be recalled that during the 1.5 gm/min injection experiment, the scrubber Kepone concentration changed such that, after a total feed of 178 gm of Kepone, the scrubber load was 3.3×10^{-2} gms (corrected for the assumed scrubber loss mechanisms). If it is now asserted that this result was a consequence of the direct challenge to the afterburner, then the efficiency of the afterburner for Kepone

*"The discussion regarding the disappearance of Kepone from the scrubber solution was particularly interesting. I believe, however, that the disappearance of the Kepone is caused by its chemical destruction in the hot caustic solution of scrubber. Our data at this laboratory show that Kepone can be completely converted to NaCl and Na_2CO_3 by exposure to caustic solution at 350°C under pressure with excess oxygen with a residence time of 5 minutes. I think that a similar process is occurring in the caustic solution of the scrubber in contact with the hot gases at a somewhat slower rate." By A.J. Frank in response to technical review solicitation, Corporate Director, Environmental Planning.

combustion was 99.981 at a temperature of 1093°C and with a residence time of the order of two (2) seconds.

To return to the coincineration experiments which involve the kiln as well as the afterburner, it is appropriate to indicate the kiln exit temperature as functions of time. The data are presented in Figures 12 through 15. It is immediately noted from Figures 12 through 14, that during these experiments, the kiln temperature was below 350°C. According to the results of Rubey and Duvall(1) Kepone is unstable at temperatures above 350°C so that it is reasonable to assume that during the experiments described by Figures

TABLE 10 Incinerator* Efficiency as Derived from Scrubber Data

Afterburner Temperature (°C)	Kepone Feed Rate to Kiln (gm/min)	Kepone Input to Scrubber (gm/min)	Efficiency of Incinerator (percent)
1149	11.2	1.19×10^{-4}	99.9989
1093	5.64	1.2×10^{-4}	99.99789
1093	24.2	-	-
1038	5.64	1.89×10^{-4}	99.9966

* Incinerator includes both kiln and afterburner but excludes possible effects due to scrubber.

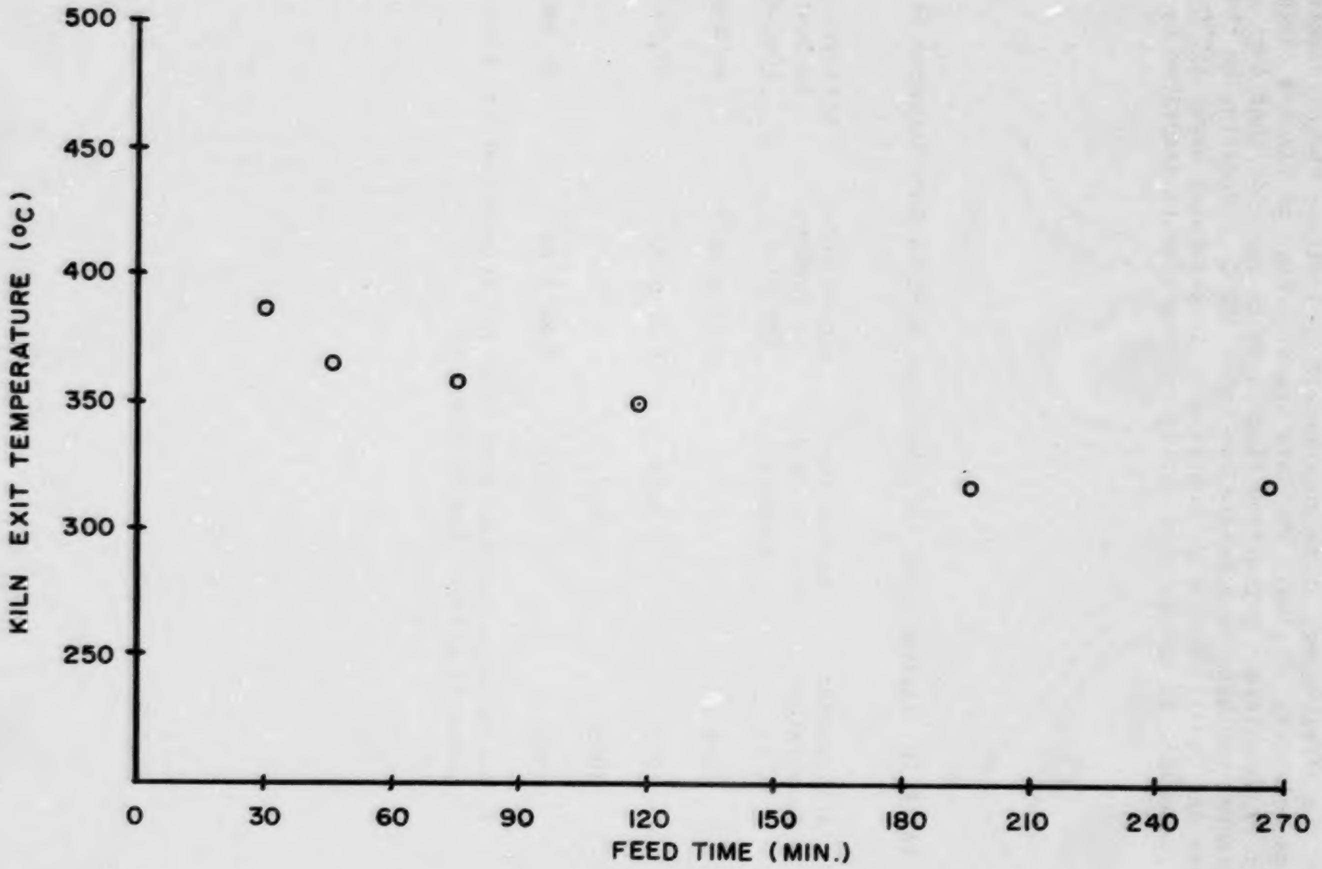


FIGURE 12 : KILN EXIT TEMPERATURE AS A FUNCTION OF TIME
5.6 gm/min., AB 1149°c COINCINERATION

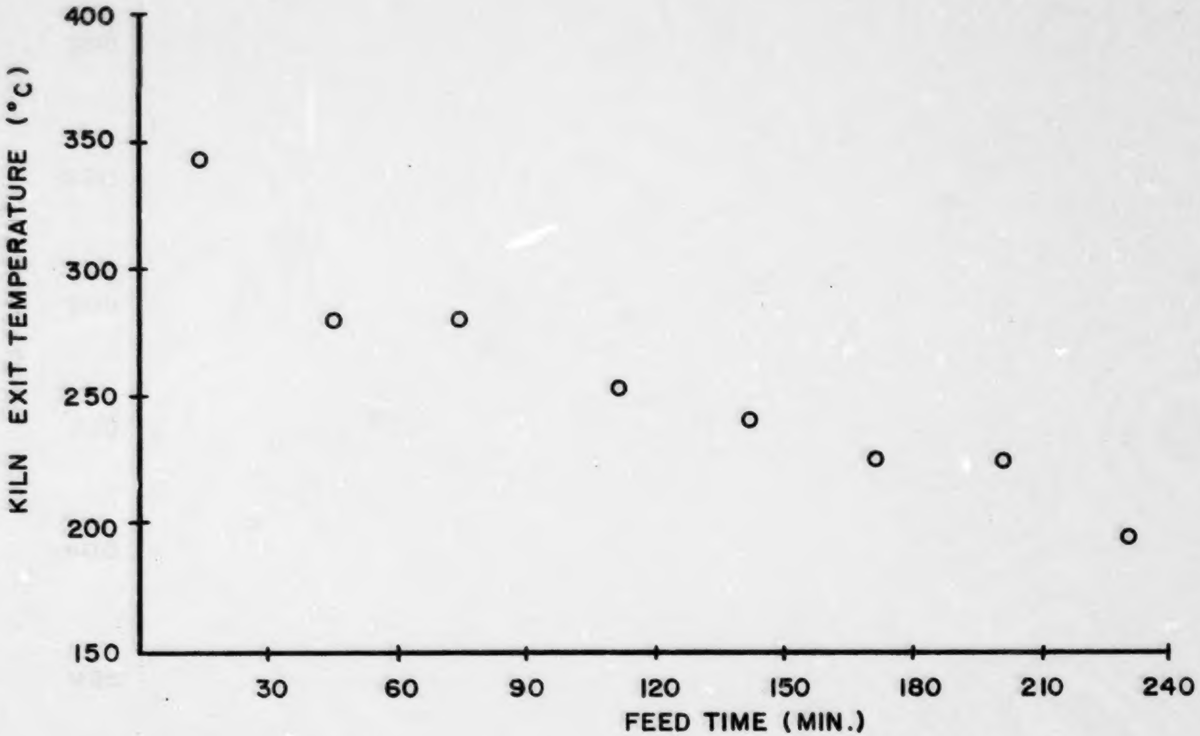


FIGURE 13 : KILN EXIT TEMPERATURE AS A FUNCTION OF TIME FEED 5.6 g/min., AB 1093°C. COINCINERATION

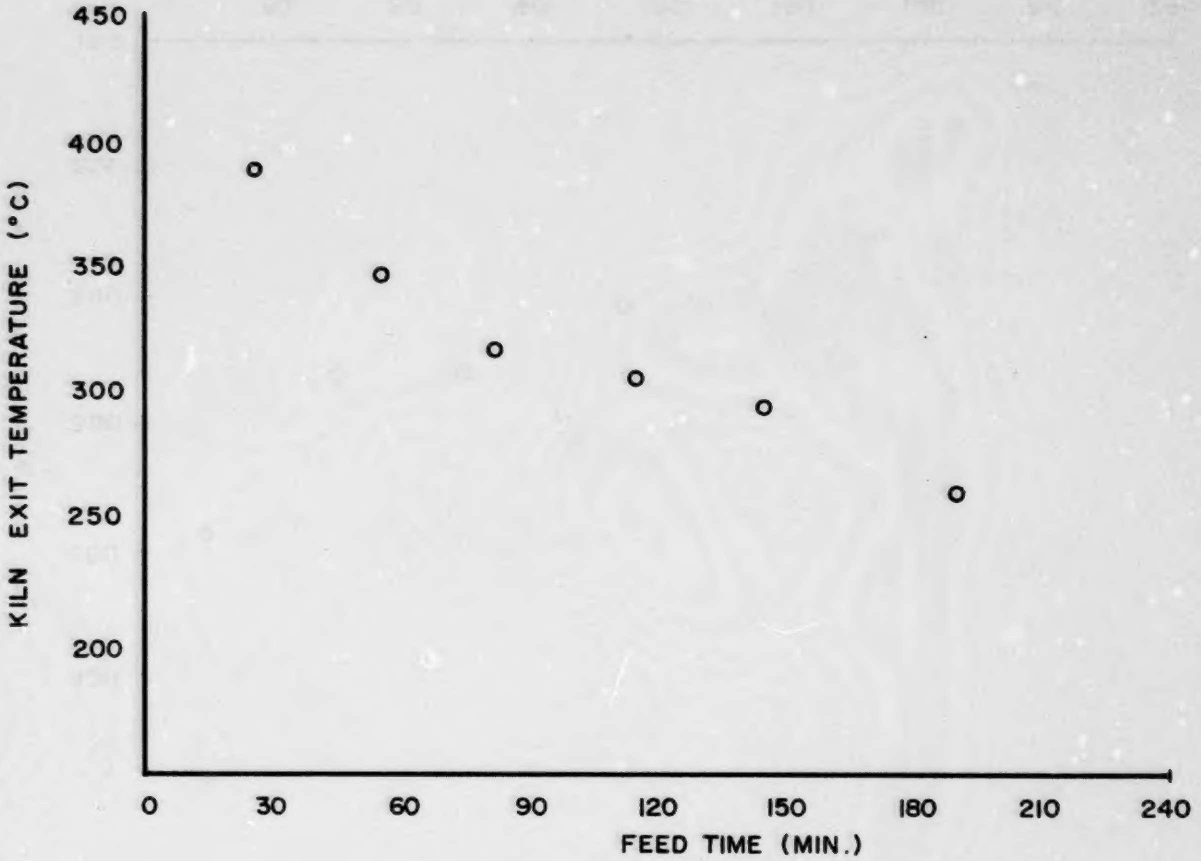


FIGURE 14

KILN EXIT TEMPERATURE AS A FUNCTION OF TIME
FEED 5.6 gm/min., AB 1038°C COINCINERATION

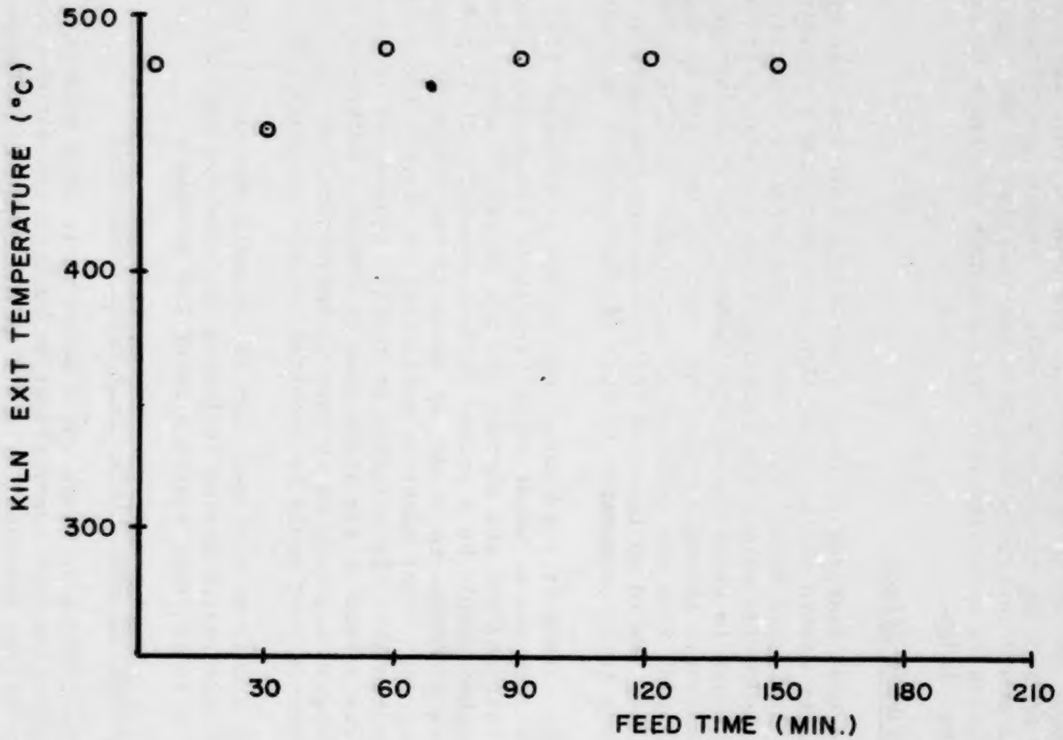


FIGURE 15 KILN EXIT TEMPERATURE AS A FUNCTION OF TIME
FEED 24.2 gm/min., AB 1093°C COINCINERATION

12 through 14, some of the input Kepone to the kiln escaped to enter the afterburner.

At this point it should be possible to unravel the separate effects due to the kiln from those due to the afterburner. Unfortunately, this possibility was not recognized in the initial phases of the experimental study so that no provisions were made to allow sampling of the (rather lengthy) duct from the kiln output to the afterburner input. Thus any serious attempt to discover the separate effects would be almost entirely speculative. There are several remarks that can be made. If we examine the kiln output temperature as shown in Figure 15, it is clear that in this case, the exit temperature never fell below 400°C and this particular experiment exhibited the behavior shown in Figure 11 wherein the scrubber Kepone load decreased throughout the entire experiment. Presumably, this behavior arose because little or perhaps no Kepone was able to escape destruction within the kiln. Thus it would certainly seem that the function of the kiln in this particular application is something more than a simple pyrolyzer to vaporize the Kepone from the sludge.

The Scrubber Effect

Several features of these experiments indicate that there are processes that occur within the scrubber that have not been illuminated by the nature of the available data. For example, the apparent association of Kepone with sodium hydroxide within the escaping stack gases is difficult to account for. In all cases in which Kepone was found in the stack sample, the fluids that were collected showed a basic pH. Further, the rate at which Kepone was "evaporated" from the scrubber as compared to the rate at which water was evaporated seemed to indicate that the kepone concentration in the stack water was quite comparable to that in the scrubber as a whole.

The nature of the Kepone destruction process(es) that are postulated to occur within the scrubber are difficult to visualize, although it should be noted that the process whereby the hot stream of gases from the afterburner is quenched should be a rather violent process. It is possible that the exposure of Kepone to these hot gases in the moment of explosive evaporation of the quench water might be sufficient to disrupt the molecule. It is even conceivable that the solution so rapidly evaporated in the quench process would contribute to the stack load of Kepone. Unfortunately, the scope of this program was such as to make it impractical to carry out the additional measurements that would be required to unravel these questions.

It should be stressed that the overall destruction efficiency for Kepone of the incinerator system including the scrubber was found to be higher than the kiln-incinerator system without the scrubber.

Observations of the Utility of a Field Laboratory

The climate in which these experiments were conducted was such that it was imperative that every effort be made to prevent the exposure of either the operations personnel or the general community to Kepone. It was also deemed essential that there be provided an on-site analytical capability to perform, on essentially a real-time basis, Kepone analyses of quality comparable to those of a standard laboratory. As indicated in Appendix C, a considerable stock of equipment and reagents was brought to the site in order to allow these analyses to be carried out. It is gratifying that the only materials that required local purchase was a supply of distilled and deionized water and ice.

In spite of the somewhat makeshift nature of the physical facilities and the rigors of the weather, it was found that trace Kepone analyses could be completed in approximately 15 minutes for aqueous samples and about 30 minutes for filters and similar materials. Such promptness allowed almost real-time results to be made available to the Burn Authority and thus greatly facilitated important decisions on program changes and continuation.

In the course of some 38 days of laboratory operation nearly 1000 individual analyses were performed by a staff of one analytical chemist and one technical assistant - this is truly remarkable.

The experience that has been gained by this activity suggests that such a portable facility can be used for many such trace organic analyses. However, the specific characteristics of Kepone, that is the relative ease with which Kepone can be separated from other chlorinated organics by base partitioning, were of importance in the speed with which sample cleanup and subsequent analysis could be accomplished. Analyses of compounds such as PCBs could be expected to be somewhat more time consuming because of the elaborate cleanup procedures that would normally be required.

Observations on the Adequacy of the Health and Safety Program

The Health and Safety Program was conceived as an integral part of the KIT program and was found to be entirely adequate. Prior to the onset of the program, all operating personnel were required to have a blood sample taken to be compared with a similar sample at the completion of the program. This test is a very sensitive measure of the magnitude of exposure that was received. In all cases there was no observed change found in the blood picture of the operating personnel.* From these data it can be asserted that no individual was exposed to measurable amounts of Kepone.

In addition, the rather extensive wipe sample program that was undertaken (as described in Appendix B) showed that the method of isolation that was employed within the facility was also entirely adequate. At no time was there detected significant evidence of contamination on the walls or floor of the operations room. On the other hand, even the contamination found within the kiln and mixing rooms was of such a nature that relatively little surface cleaning was required prior to the disassembly of the facility.

The success of the approach used in the KIT program suggests that similar methods could be of great utility in any installation that is involved in the handling of toxic materials.

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*See Appendix H

An interesting side light on the need for training is the need for and the use of protective equipment was brought out by the acetic acid spill which occurred during the coldest weather in Toledo. The freezing point of glacial acetic acid is some 16.6°C so that it was frozen when the 55 gallon containers were brought into the mixing room. Valiant attempts to thaw the material finally led to the use of a heating belt on the can. Unfortunately, the can overheated and caused the plastic liner to be ruptured. By a strange series of circumstances, this particular container had a small opening near the bottom of the can, so that with the integrity of the liner breached, acetic acid began to leak onto the floor. In the excitement of the moment, the container was turned on its side with the result that a significant amount of the acid was allowed to spill onto the floor. In any event, the entire incident was cleaned up with only one very small skin burn resulting - this in spite of the very corrosive nature of glacial acetic acid.

Some General Observations

The Surface Combustion facility was not constructed specifically for the KIT program. This fact introduced several factors into the program that merit further discussion.

The kiln, which was designed for batch operations, was not new and thus suffered a number of breakdowns that served to delay the program. The sludge feed, which was to be continuous, was accomplished by the makeshift introduction of a water cooled line through the hot exit gas duct into the kiln. This procedure apparently resulted in the flash evaporation of Kepone without allowing it to remain for a time in contact with the drying sludge. It was probably fortunate that Kepone is degraded at temperatures of the order of 350-400°C, since otherwise a great deal more of the material would have been presented to the afterburner. In addition, sludge was noted to fall from the walls of the kiln onto the cooled water line with the result that there was a considerable buildup of partially combusted material on the line. At the end of the run this deposited material was found to be admixed with the ash so that ash concentration measurements were not particularly meaningful.

Because of the particular arrangement of the components of the system, there was an excessively long duct run from the kiln to the afterburner. In spite of the frequently expressed fears that Kepone deposition on the walls of this duct would vitiate the results of the experiment, there was no evidence of such a deposition when the experiments were finished. Nevertheless, the use of such a long duct run certainly decreased the thermal efficiency of the system.

A number of unexplained phenomena plagued the injection runs. The successive stack sampling runs were almost impossible to explain in terms of the measured water content, which was found to fluctuate wildly. After a new stack fitted with a reheater was installed, there were no such variations noted. A possible explanation of these results might lie in the extreme weather that occurred during the earlier experiments: it was cold enough that the plume was actually formed within the stack such that variations in the actual level at which it formed would account for the variations in the observed results. On the other hand, some of the stack water samples that were collected showed rather high pH, of the order of 9 to 10, and only when there was a high pH was there Kepone found in the stack. In the experiments that involved the coincineration (with the newly installed stack and reheater) no such high pH waters were collected even though traces of Kepone were detected in the higher level experiments.

The obvious failure of the injection head-afterburner combination in Experiment 5 does not lend itself to a ready explanation. The injection head design was not conventional, as is discussed in Section 4.3.1, and could not be directly tested for its ability to entirely vaporize the acetic acid solution under the conditions that occur within the feed duct. On the other hand, the flame out detector within the afterburner was not sufficiently rapid in response to preclude a momentary flameout with the result that considerable gas could pass through without the normal residence time. In the analysis of the scrubber effect in Section 7.2, it could with justification, be assumed that the observed Kepone feedthrough in Experiment 5 was in fact due to the lack of thermal capacity of the afterburner and thus these results do represent the efficiency of the afterburner. If this is assumed to be true, then it seems that the primary destruction of Kepone occurred within the pyrolyzer.

The Surface Combustion incinerator system depended on the fan located on top of the scrubber to provide the motive force for gas transport through the entire system. In particular, the ambient pressure within the kiln was maintained at slightly below atmospheric by the combined effect of this fan and the gases generated by the flame input to the kiln as well as from the evaporating water and combustion fumes from the sludge. During the period wherein the coincineration experiments were being conducted, there is evidence that the kiln experienced excursions of positive pressure. Part of the evidence for this statement arises from visual observation of steam rising from the ports on the kiln, from the observation of smoke during the period after the sight glass fell out but more strongly from the observation of Kepone losses from the kiln. The latter information derives from the observation that the high volume sampler that was located on the roof of the Mixing Room so as to sample the exhaust fan from the kiln room. During the period 18 February through 25 February, this sampler picked up Kepone emissions. During this same time, the level of Kepone found in the stack was very much below that detected by the high volume sampler. Fortunately, other high volume samplers located down wind from the offender showed that dilution effects had reduced the observed levels to well below the action level.

The discussion on the Scrubber Effect in Section 7.2 indicated that there was actually no provision for the determination of the actual volume of the scrubber at any particular time. This necessitated that one assume a volume and calculate the level effects. Had the system been designed for research, such provisions would surely have been made.

REFERENCES

1. Duvall, D. S., and Rubey, W. A., Laboratory Evaluation of High-Temperature Destruction and Pesticides, EPA/2-76-299, December, 1976.

2. "Standard of Performance for New Stationary Sources," Federal Register 36 (247): 24876-24895 (23 December 1971).

APPENDICES

APPENDIX A. FACT SHEET - KEPONE BURN

1. Data from Duvall and Rubey at UDRI have shown that Kepone is completely destroyed at temperatures in excess of 500°C (932°F) (Figure 21, their report). These results were obtained in dry air without flame and with 1 sec residence time.

2. Data from Duvall and Rubey at UDRI also show that DDT (p-p'-DDT) under similar conditions is completely destroyed at 450°C (842°F).

3. Work by Versar (Contract 68-01-1587) demonstrated a destruction ratio of over 99.99% for DDT during coincineration with sewage sludge at 650°C (1200°F) nominal temperature and afterburner residence times on the order of 0.1 sec.

4. The inference from the above is that the conditions within the surface combustion furnace/afterburner (1426°C - 2600°F with residence time of 2 sec) is more than adequate for complete destruction of Kepone.

5. The experimental protocol is designed as follows:

   Exp. 1. Injection of Kepone solution at the rate of 2.5×10^{-5} gm/min for a total injection time of 4 hr for a total injection of 6 mg (0.0002 oz) of Kepone.

   The stack sampling and subsequent analysis is capable of detecting a quantity of Kepone that is less than 1 millionth of the hourly injection rate. Thus, in this primary experiment, even if the afterburner had no effect on the Kepone, the airborne concentration at the ground 100 ft from the stack would not exceed 2.8×10^{-8} gm/m^3 = 2.5×10^{-11} gm/liter.

   Assume that a 145-lb human has a lung tidal rate on the order of 5 liters/min and he is exposed to Kepone-laden air at a level of $2.5 \times 10^{-11} \times 5 \times 60 \times 4 = 3 \times 10^{-8}$ gm.

   Published data(2) suggest $LD_{50} \sim 1.32 \times 10^{-1}$ gm/kg body weight for Kepone in rats. Assume that the same LD_{50} obtained for humans; then

   $$145 \text{ lb} \equiv 66 \text{ kg}$$

   $$LD_{50} \sim 8.7 \text{ gm}$$

   Hence total exposure $\sim\frac{3}{100,000,000}$ of LD_{50} dose.

Needless to say, no such exposure is reasonable to expect, and the evidence for complete combustion of the Kepone is persuasive.

6. The total amounts of Kepone to be used in the preliminary experiments are as follows:

   (1) 6×10^{-3} gm
   (2) 0.60 gm
   (3) 60 gm
   (4) 6000 gm
   (5) 0.60 gm
   (6) 0.60 gm

   TOTAL 6.062×10^3 gm = 13.4 lb

7. Safety Arrangements:

   (a) General Public

   In view of the computation in Section 5, a level of Kepone emission (measured at the stack) of less than 1×10^{-6} gm/m^3 is sufficiently stringent to assure public protection. The analytical/sampling techniques involved are capable of detecting 5×10^{-12} gm Kepone, which for a 1 m^3 sample (∿28 ft^3) represents an emission level 100,000 times below the safe level.

   On the completion of an experiment, the analytical data will be examined by a committee of senior environmentalists representing the community, the state, and the Federal EPA. This group will have the final say as to whether it is safe and prudent to go to the next step of the experiment. In all cases, an emission that approaches the limit of 1×10^{-6} gm/m^3 will preclude proceeding further.

   (b) Laboratory Personnel and Observer

   (1) All Kepone used in this experiment will be in the form of solutions in sodium hydroxide/water and will be maintained in sealed containers. Feed of these solutions will be through tygon tubing directly into the furnace. At no time will Kepone feed solutions be exposed to the laboratory air.

   (2) All safety and health precautions will be directed and overseen by the Safety Group made up of recognized representatives of local and state health departments.

   (3) All personnel entering the laboratory will receive blood tests before and after possible exposure.

8. Pilot-Scale Experiments

With the successful completion of the direct injection experiments (#1 through 6), additional experiments will be conducted with sewage sludge and soil samples, as follows:

(7) Uncontaminated sludge

(8) Hopewell sludge

(9) Kepone-injected sludge

(10) Kepone-containing sediments

(a) Kepone quantities

The Hopewell sludge contains ∿ 1 ppm Kepone,

thus: 1000 lb sludge - 0.5 gm Kepone

injected sludge I - 2×10^4 gm Kepone

injected sludge II- 4×10^4 gm Kepone

sediments - 2.5 gm Kepone

The injection process will require that Kepone solution be injected into the sludge just before the admission of the combined Kepone sludge into the furnace. The entire experiment, if completed, will involve at most approximately 150 lb Kepone. Actually, a total of 150 gal of Kepone solution is involved at most.

It is planned to initially ship 15 gal of Kepone solution to the test site. This is sufficient to complete the first six experiments. Only after these experiments have been successfully run will the additional material be shipped.

(b) Sampling/Analysis

In the pilot-scale experiments, sampling and analysis will be extended to scrubber water (which will be impounded until it is determined that there is no Kepone therein) and to the furnace residuals; these in addition to the stack sampling.

9. Waste and contaminated materials:

(a) Experimental Program is Completed as Proposed - Case I

At the completion of the experiment, all contaminated equipment, supplies, and residues will be incinerated, with the usual test and analytical procedures being used. This will be effective since the fact that the experiments have been allowed to go to completion infers that the incineration does indeed completely remove Kepone.

(b) Experimental Program Terminated Before Completion of Proposed Work-Case II

Early termination of the experiment will result from the failure of incineration to completely destroy Kepone. In this event, all contaminated materials, supplies, and equipment will be dismantled and returned to Hopewell in sealed containers.

APPENDIX B. WIPE TEST PROCEDURE

Open the Wipe Test Packet. Remove the gloves from the packet and put them on without bringing the outside of the gloves into contact with anything other than the gloves or the inside of the glove package.

Remove the sampling paper envelope and the sampling scale. Take the 15-cm Whatman #4 paper in the right hand. Place the 30-cm sampling scale against surface to be wiped with the left hand. Wipe the surface the length of the sample scale.

Move the sampling scale to a new location.

Wipe five separate areas for each sample.

Replace the filter in the envelope, seal it, and record the location, date, time, and initials of sampler.

TABLE B-1 KEPONE WIPE SAMPLES 1/12/77

Sample#	Description	Wipe Sample (micrograms / 1125cm2)	Level of Contamination (microgms/sq.ft.)
1	blank	.003	.002
2	walls & floor of lab	.01	.008
3	walls of lab	ND	ND
4	floor-kiln rm.	ND	ND
5	walls-kiln rm.	ND	ND
6	floor-mixing rm.	ND	ND
7	walls-mixing rm.	ND	ND
8	floor-all rooms shower trailer	ND	ND
9	walls-all rooms shower trailer	ND	ND
10	control rm. floor	ND	ND
11	control walls & equipment	ND	ND
12	sampling platform floor	ND	ND
13	sampling platform walls & equipment	ND	ND

*ND = No Kepone detected in sample.

TABLE B-2 KEPONE WIPE SAMPLES 1/24/77

Sample#	Description	Wipe Sample $\left(\frac{\text{micrograms}}{1125\text{cm}^2}\right)$	Level of Contamination (microgms/sq.ft.)
14	mixing rm. walls before opening Kepone	2.53	2.08
15	mixing room floor before opening Kepone	0.15	0.12
16	mixing room floor after opening Kepone	0.35	0.29
17	mixing room walls after opening Kepone	-*	-
18	kiln room floor after opening Kepone	-	-
19	kiln room walls after opening Kepone	ND	ND
20	lab floor	ND	ND
21	lab walls	ND	ND
22	locker rm. floor	ND	ND
23	locker rm walls	ND	ND
24	shower rm. walls	ND	ND
25	shower rm. floor	0.0197	0.0163
26	sampling platform floor	0.014	0.011
27	sampling platform walls	ND	ND
28	operations & control rm. floor	-	-
29	operations & control rm. walls	0.028	0.023
30	change room floor	ND	ND
31	change room walls	ND	ND

*Laboratory accident, sample lost.

TABLE B-3 KEPONE WIPE SAMPLES 1/31/77

Sample#	Description	Wipe Sample $\left(\frac{\text{micrograms}}{1125\text{cm}^2}\right)$	Level of Contamination (microgms/sq.ft.)
32	change rm. floor	<0.02	<0.02
33	hallway floor	<0.0112	<0.092
34	blank	<0.02	<0.02
35	mixing rm. floor	<0.02	<0.02
36	mixing rm. walls	<0.02	<0.02
37	kiln room floor	<0.02	<0.02
38	left in change rm.	-	-
39	left in change rm.	-	-

TABLE B-4 KEPONE WIPE SAMPLES 2/22/77

Sample#	Description	Wipe Sample $\left(\frac{\text{micrograms}}{1125\text{cm}^2}\right)$	Level of Contamination (microgms/sq.ft.)
43	kiln rm. walls	0.0015	0.0012
44	kiln rm. floors	0.0024	0.0020
45	mixing rm. floor	1.56	1.29
46	--- *	ND	ND
47	---	ND	ND
48	mixing rm. walls	0.36	0.30
49	mixing rm. floor in area of spill	1.8	1.5
50	hall floor	0.78	0.64
51	change rm. floor	0.0134	0.0110
52	sampling platform floor	0.186	0.153
53	sampling platform walls	ND	ND
54	operation & control room floor	ND	ND
55	operation & control room walls	ND	ND
56	laboratory floor	ND	ND
57	laboratory walls	ND	ND
58	locker room floor	ND	ND
59	locker room floor CLEAN	0.3	0.2

*Sample identification lost in transit.

TABLE B-5 KEPONE WIPE SAMPLES 2/25/77

Sample#	Description	Wipe Sample $\left(\frac{\text{micrograms}}{1125\text{cm}^2}\right)$	Level of Contamination (microgms/sq.ft.)
60	kiln rm. walls	0.17	0.14
61	change rm. floor	0.17	0.14
62	change rm. walls	0.00008	0.00007
63	---	0.4	0.3
64	hall walls	0.00008	0.00007
65	mixing rm. walls	0.00048	0.00040
66	mixing rm. floor	0.00252	0.00208
67	kiln rm. floor	0.00004	0.00003
68	locker rm. floor	0.02	0.02
69	locker rm. walls	ND	ND
70	shower rm. floor	0.00005	0.00004
71	laboratory walls	ND	ND
72	laboratory floor	ND	ND
73	shower rm. walls	0.00005	0.00004
74	---	0.00002	0.00002
75	control rm. floor	ND	ND
76	samp. plat. floor	ND	ND
77	samp. plat. walls	ND	ND
78	control rm. walls	ND	ND

TABLE B-6 KEPONE WIPE SAMPLES 3/1/77

Sample#	Description	Wipe Sample $\left(\frac{\text{micrograms}}{1125\text{cm}^2}\right)$	Level of Contamination (microgms/sq.ft.)
79	samp. plat. floor	0.08	0.07
80	control rm. walls	0.05	0.04
81	locker rm. floor	0.13	0.11
82	locker rm. walls	0.13	0.11
83	shower rm. floor	0.26	0.21
84	shower rm. walls	0.40	0.33
85	samp. plat. walls	0.06	0.05
86	control rm. floor	0.08	0.07
87	lab floor & counter (northside)	0.13	0.11
88	lab trailer Southside (office)	0.26	0.21
89	change rm. floor	12.4	10.1
90	change rm. walls	0.52	0.43
91	VOID	-	-
92	hall floor	43.3	35.8
93	hall walls	1.6	1.3
94	mixing rm. floor	36.6	30.1
95	mixing rm. walls	3.66	3.01
96	kiln rm. floor	3.0	2.5
97	kiln rm. walls	1.4	1.2

TABLE B-7 KEPONE WIPE SAMPLES 3/3/77

Sample#	Description	Wipe Sample $\left(\frac{\text{micrograms}}{1125\text{cm}^2}\right)$	Level of Contamination (microgms/sq.ft.)
99	change rm. floor	ND	ND
100	hall floor	1.89	1.56
101	hall walls	0.04	0.03
102	mixing rm. floor	3.3	2.7
103	mixing rm. walls	0.2	0.2
104	kiln rm. floor	0.3	0.2
105	kiln rm. walls	0.05	0.04

TABLE B-8 KEPONE WIPE SAMPLES 3/7/77

Sample#	Description	Wipe Sample $\left(\frac{\text{micrograms}}{1125\text{cm}^2}\right)$	Level of Contamination (microgms/sq.ft.)
106	hall floor	<0.01	<0.01
107	mixing rm. floor	<0.01	<0.01

APPENDIX C. LABORATORY EQUIPMENT AND SUPPLIES ON SITE

Laboratory Equipment

The laboratory equipment that was transported to the site consisted of the following items:

Gas Chromatograph - Hewlett Packard Model 5700 series equipped with a Ni^{63} electron capture detector and a Hewlett Packard Model 3380A Integrator for both peak area determinations and for the preparation of a hard copy of the chromatogram.

Gas chromatographic columns of pyrex glass (180 cm long x 4 mm ID) packed with:

a. 5% OV-210 on gas chrom Q (100-120 mesh)

b. 1.5% OV-17 + 1.95% QF-1 on gas chrom Q (100-120 mesh)

c. 3% OV-210 on gas chrom Q (100-120 mesh)

d. 10% OV-1 on chromosorb-W (AW).

Concentrator - An elevated (45°C) evaporator using a gentle (5-10 ml/min) stream of dry nitrogen gas.

Assorted Glassware -

a. Graduated cylinders, 10, 50, 250 ml - one dozen each

b. Erlenmeyer flasks with ground glass stoppers: 25, 50, 100, 250, 500 and 1000 ml - one dozen each

c. Separatory funnels with teflon stop cocks: 50, 125, 500, 1000 and 2000 ml - six of each

d. Pipets - Pasteur, glass disposable, 1, 2, 5, 10 ml - 6 dozen of each

e. Evaporative flasks and test tubes - graduated 15, 50 and 250 ml - two dozen of each

f. Microsyringe, 10 μl - six dozen

g. Tweezers, spatulas, etc., teflon coated

h. Glass columns with fritted discs and reservoirs.

Reagents, Solvents and Standards

a. Benzene, methanol, hexane, isoctane, petroleum ether, diethyl ether (all pesticide grade, glass distilled)

b. Sodium sulfate Fisher Certified, granular, anhydrous

c. Florisil, activated

d. Sulfuric and hydrochloric acid, Fisher Certified (ACS) extracted with benzene

e. Sodium hydroxide 1.0N (ACS) pre-extracted with benzene

f. Triple distilled water

g. Reference Materials:

   1. Kepone, hexachlorobenzene, hexachlorocyclopentadiene, mono and dihydro Kepone, reference grade all provided by U.S. EPA

   2. Stock standard Kepone solutions - 200 μg/ml in 98% benzene + 2% methanol (EPA)

   3. 1 μg/μl in benzene from anhydrous Kepone used as secondary reference

h. Working standard solutions of Kepone and possible degradation products

5 pg/μl*
10 pg/μl
30 pg/μl   all in 99% benzene + 1% methanol
50 pg/μl
100 pg/μl

* pg = 1 x 10^{-12} gm.

APPENDIX D. PRE-BURN EXPERIMENTAL PROTOCOL

Incineration Test Program Objective

The proposed incineration test program will establish procedures for the incineration of the Kepone contaminated sewage sludge at the lagoon in Hopewell, Virginia. It will also help establish public confidence in programs for the incineration of Kepone and Kepone contaminated substances.

The following information regarding the incineration of Kepone and Kepone contaminated substances will be studied by this program:

The effectiveness of incineration to destroy Kepone (and its hazardous byproducts) at various time-temperature combinations and Kepone concentrations.

The effectiveness of incineration to produce a residue free from Kepone (and its hazardous degradation products) which can be safely disposed of by normal means.

Parameters for sludge decontamination and incineration.

Parameters for equipment design.

Background Technology

General - The following summary of information applicable to this incineration test provides the background for the technology to be employed in this incineration test.

Laboratory Evaluation of High Temperature Destruction of Kepone and Related Pesticides --

University of Dayton Research Institute
D. S. Duvall and W. A. Rubey
May 1976

Abstract -- The serious problems concerning the Kepone Manufacturing operations in the Hopewell, Virginia area have been widely publicized. Disposal problems and environmental cleanup associated with Kepone being found in soil, water, sewage sludge, etc., have been substantial. Thermal disposal was considered to be a primary means for solving this disposal problem. However, basic high-temperature data on Kepone were lacking; accordingly, the objectives of this study were directed to provide necessary information.

This study was concerned with thermal destruction testing conducted with three pesticides: Kepone, Mirex, and DDT. A specialized laboratory technique incorporating a two-stage quartz system (vaporization first, then high-temperature exposure) was developed. It is important to note that in this system the pesticide was first converted to the gas phase, then exposed to the high-temperature destruction conditions. Critical parameters of temperature and residence time were accurately measured. Both the Kepone and DDT molecules, at a residence time of 1 sec, were essentially destroyed at 500°C; however, Mirex, at the same residence time, required 700°C for destruction.

EPA's Chemical Waste Incineration Program by John Schaum and Alfred Lindsey, 1975.

Engineering Feasibility Report - Destruction of Kepone Contaminated Waste in the Lagoon located at the Hopewell Sewage Treatment Plant by Design Partnership, May 20, 1976.

Conference - Toledo, Ohio, 23 June 1976 - This meeting between representatives from EPA, the State of Ohio, the City of Toledo, D. P. Versar, Inc., and Surface Division, Midland-Ross dealt with the activities related to the incineration test of Kepone in Toledo and public reaction.

Conference - Washington, DC, 8 July 1976 - This meeting held at EPA was attended by representatives of EPA, the Commonwealth of Virginia, the State of Maryland, University of Dayton Research Institute, Allied Chemical, and D. P. Versar, Inc. The purpose of the discussion was to share technology concerning the thermal destruction of Kepone.

Project - 437 - 1973 - Research of Pesticide Disposal by Sewage Sludge Incinerators by Versar, Inc.

Project - 465 - 1975 - PBC Incineration by Versar, Inc.

Project - 454 - 1974 - Microeconomic Analysis for Selected Toxic Substances by Versar, Inc.

Project - 474 - 1974 - Microeconomic Study of Various Toxic Substances by Versar, Inc.

Project - 461 - 1975 - Gas Stream Sampling by Versar, Inc.

Project-464 - 1975 - Water and Waste Water Analysis by Versar, Inc.

Determination of Incinerator Operating Conditions Necessary for Safe Disposal of Pesticides by Thomas L. Furguson, Fred J. Bergman, Gary R. Cooper, Raymond T. Li and Frank I. Honea - EPA-600/2-75-041

Summation of Conditions and Investigations for the Complete Combustion of Organic Pesticides by Boyd T. Riley, Jr. EPA-600/2-75-044

Authority, Participants, and Observers

The incineration test is being done for the Kepone Task Force of Virginia. Due to the nature of the chemical involved and the concern with public and environmental safety, the incineration test program will be under the direction of the Test Burn Authority.

Incineration Test Authority -- The Incineration Test Authority will be made up of officials from the Commonwealth of Virginia, EPA/MERL, Toledo Pollution Control Agency, EPA Region V and Ohio EPA.

The Authority will have the following responsibilities:

Direct the test program and authorize decisions required during the test progression.

- Interface with regulatory agencies.
- Prepare and authorize all press releases.
- Transport and dispose of residues.
- Assure the public safety.

The Incineration Test Management Group -- The Incineration Test activities are under the direction of Design Partnership, Inc., consultants to the Kepone Task Force. The consultants have arranged for Surface Division, Midland-Ross to provide the incineration test facilities and Versar, Inc., to provide testing and laboratory services. Representatives of these firms will form the Incineration Test Management Group with the following structure:

- The Project Manager will be from Design Partnership and will be in overall control of the project.
- The Operations Manager will be from Surface Division, Midland-Ross and will be in charge of incineration operations.
- The Sampling and Testing Manager will be from Versar, Inc., and be responsible for all sampling and laboratory work.
- Industrial Hygienist

The Incineration Test Management Group will have the responsibility and authority for the following aspects of the project:

- Safety and Hygiene on the incineration test site.
- Burn procedure.
- Documentation.

Observers -- Other people, agencies, and organizations interested in the incineration test will be considered visitors and observers and will be admitted only by invitation of the Incineration Test Authority.

Description of Facilities

The Incineration test will be done at the Research Laboratory of Surface Division, Midland-Ross in Toledo, Ohio.

Incineration Equipment -- The following equipment is available in the Research and Development Laboratory:

Rotary kiln pyrolyzer -- The Rotary Kiln Pyrolyzer is five feet in diameter and 10 ft long. It rotates at 1 rpm and has capability for continuous loading and unloading as well as two hatches for batch loading and unloading. It is heated directly by hot gases and from a 1 MM BTU/hr capacity burner. Charge and discharge connections for the hot gases have rotary seals to prevent leakage of gases into or out of the kiln. The kiln can be operated at about 1000°F.

Fume incinerator (high temperature afterburner) -- The Fume Incinerator to be used for the pilot tests is equipped with two 500,000 BTU/hr capacity throat mix burners. The residence chamber volume is about 30 ft^3. The incinerator is furnished with temperature controller and high limit safety shut-off instrumentation.

Quench -- Quench is used to cool the gases from the incinerator by evaporative cooling. It is equipped with recirculation tank, pumping system, and spray nozzles. Emergency cooling water spray nozzle is also provided.

Scrubber -- Scrubber is a 30-in. diameter tower packed with 2-in. intalox saddle plastic packings. The packed bed height is about 6 ft. Scrubbing is done by 18% caustic solution flowing counter current to gas stream. The scrubber is equipped with I.D. fan and recirculation tank. Scrubbing fluid pH is controlled by adding caustic solution. Liquid level in the recirculation tank is maintained by adding make-up water. A controlled quantity of liquid is purged from scrubber to a brine retention tank continuously.

Sampling and Analysis Equipment --

The following equipment is either available at the Research and Development Laboratory, or will be brought to the site by Versar, Inc.:

1. O_2, CO, CO_2, and Hydrocarbon Analyzers (available)

2. The gas chromatograph and its related equipment which includes a Hewlett Packard Model 5710A gas chromatography system and a Fisher Model 5000 integrating recorder. The gas chromatograph is equipped with an electron capture detector (Ni^{63}). Two types of columns are used: A nonpolar 3% OV-1 on 100-200 mesh gas chrom Q. Moderately polar, i.e., 1.5% OV-17 + 1.95% OF-1 on 100-200 mesh gas chrom Q.

These columns have been tested with analytical standards of Kepone and HCB standards and have been found to be heat stable, efficient and to have good resolving power.

3. RAC Staksampler, control unit, sampling box with stainless steel sampling probe and pitot assembly and all the assorted glassware.

4. The feed assembly including pump, feed lines and injection probe.

Facilities --

The facilities on location will include the incineration test facility, a sample testing laboratory, a conference room, and a temporary office for the use of the Incineration Test Authority and the Incineration Test Management Group.

Sample Transportation

Pure Kepone -- Pure Kepone will be transported to Toledo, Ohio, in double sealed containers.

Kepone Contaminated Sludge --

Kepone contaminated sludge will be supplied by the Kepone Task Force of Virginia. The sludge will be loaded in sealed drums at the lagoon in Hopewell, Virginia and transported to Toledo, Ohio. The sample will be two 55-gal drums (30 - 65% solids, 0-57 ppm Kepone).

Blank Sludge --

Blank sludge will be obtained from a sewage treatment plant in the Toledo area and transported to the site.

Incineration Test Program

The critical aspect of the proposed program lies in the cumulative toxic nature of Kepone which imposes the necessity of absolute assurance that there is no loss of this material to the environment as a result of these tests. The absolute sensitivity of the analytical methods available are very high: Specifically, the gas-chromatograph electron capture detector (G.C.E.C.) is capable of unambiguous detection of $2 - 3 \times 10^{-12}$ gm of Kepone. Thus, by suitable selection of the size of the samples that are taken from the emergent streams from the incinerator, highly sensitive observation of all residual matter may be made.

The stack exhaust stream is the only uncontrollable output stream from the incinerator and hence represents the critical path to the environment. In the absence of a published emission standard, it is proposed to adopt the criterion of safety as being an emission (at stack temperature) not to exceed 1×10^{-6} gm/m^3. This factor is such that, on dispersion and dilution in the atmosphere, the resulting ambient air concentration would be less than 2.5×10^{-8} gm/m^3 (this latter concentration has been taken to be the interim permissible limit to be used until promulgation of a suitable standard) when account is taken of the dilution factor of 40 or more.*

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*The hot polluted stream from the stack ejected into the surrounding air creates considerable turbulence, which with the natural mixing due to air currents, causes rapid dilution and mixing of the emergent plume. Under these circumstances, according to Smith(1), the concentration of any given pollutant appears, at least initially, to decrease exponentially with the distance from the point of emission, according to the empirical equation

$$C(x) = C(o)K x-p$$

where x is the (downwind) distance, K is a parameter that describes the source and the nature of the specific pollutant, and p is a parameter varying between 1.5 and 2. Since the values of K can vary between 0.1 and 10, it is seen that the concentration at a point 100 ft downwind would be of the order of 1 percent of that at the stack. More complex descriptions have been given, but the general result is much the same as that from Smith. See also Cadle(2).

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(1) Smith, M.E., "Chemical Reactions in the Atmosphere." Interscience, New York, 1961.

(2) Cadle, R.D., "Particle Size," Reinhold, New York, 1965, pp. 267 ff.

Initial Program--

The initial phase of the program is designed to determine the efficiency of combustion of Kepone under conditions that guarantee complete safety. This phase consists of conducting a series of tests with the injection of Kepone solutions directly into the duct leading from the kiln to the fume incinerator.

Initial test -- The initial test will involve the injection, upstream of the fume incinerator, of Kepone solutions at a rate of 2.5×10^{-5} gm/min which is sufficiently low that, even in the absence of any combustion, the emergent stack stream concentration would not exceed the criterion emission level. Sampling of the stack stream will be carried out such that levels of less than 1 percent of the criterion emission level will be detectable. After suitable assurance that combustion is complete, additional direct injection tests will be conducted at increasing concentrations until it is clear that conditions existing with the fume incinerator are such as to completely combust the Kepone. On the completion of these preliminary low level tests the program will proceed to larger scale studies with sewage sludge.

Kepone solution will be injected into the duct at a rate that will insure that, even in the absence of combustion, the emergent (stack) level will not exceed the criterion level of 1×10^{-6} gm/m^3. During this test the fume incinerator will operate at 2300°F while samples of particulate and gaseous matter are conducted.

Follow-up tests -- Upon the successful completion of the initial test(by successful, it is meant that the emergent Kepone level is less than 1 percent of the permissible level) additional tests will be conducted at increasing Kepone levels as follows:

Test	Temp. (°F)	Time (sec)	Rate (gm/min)
1	2300	2	2.5×10^{-5}
2	2000	2	2.5×10^{-5}
3	2000	2	2.5×10^{-2}
4	2000	2	25
5	2000	1	25
6	1900	1	25

In each case, triplicate stack samples, taken in sufficient volume to allow detection of 1 percent of criterion emission rate, will be analyzed before the next test is conducted.

In all cases following the initial test, samples of all aqueous streams will also be taken for analysis.

Consultation -- At the completion of the analyses for each test, a decision by the Incineration Test Authority will be made as to the safety in progressing to the next test.

Kepone injection -- As indicated in Section 5 the Kepone solutions will be injected into the hot gases from the kiln at some convenient point before entry into the fume incinerator. A stainless steel nozzle assembly will be fabricated and will project through the wall into the duct. The assembly will be provided with leak-tight seals at the point of entry. Kepone solutions will be introduced through a metered peristaltic pump from a closed reservoir at rates as indicated below:

Test 1 - 10 ml/min of solution containing
2.5×10^{-3} gm/liter of Kepone

Test 2 - 10 ml/min of solution containing
2.5×10^{-3} gm/liter of Kepone

Test 3 - 10 ml/min of solution containing
25 gm/liter of Kepone

Test 4 - 200 ml/min of solution containing 125 gm/liter of Kepone
5 Same as 4
6 Same as 4

The above tests will require a total of 80 liters of solution made up at 125 gm/liter of Kepone in NaOH solution (approximately 22 gal).

The feed line external to the furnace injection line will be of tygon which will be incinerated at the completion of tests.

Pilot Scale Test --

On the successful completion of the preliminary test, attention will turn to practical scale tests. In each case all emergent streams will be sampled during the run and advancement to the next step would be conditional upon satisfactory completion of the previous step. In all cases, the emission will be the controlling factor.

The specific practical scale program will be as follows:

- Sludge blank - some 1,000 lb wet weight (18% solids) of sludge obtained locally will be incinerated.
- Hopewell sludge - some 500 lb wet weight (18% solids) of Hopewell sludge containing up to 500 ppm (dry weight) will be incinerated.
- Doped sludge - 1,000 lb wet weight (18% solids) sludge obtained locally will be doped to the level of 25% dry weight Kepone and will be incinerated.

Doped sludge - 1,000 lb wet weight (18% solids) of sludge obtained locally will be doped to the level of 50% dry weight Kepone and incinerated.

In each case the sludge will be injected by Moyno pump at a rate of 100 lb/hr of sludge. Each run will be of sufficient duration as to allow triplicate (quadruplicate for the sludge containing Kepone) stack gas sampling. In addition, periodic samples of the scrubber liquor and the scrubber water will be taken.

Sampling and Analysis

As in the case in all situations wherein it is necessary to sample streams of gases of liquids, the size of the sample and the method whereby it is taken are established by the dual requirements of allowable levels of the particular contaminant and the ultimate sensitivity of the analytical method.

In the case of Kepone, the final detection and quantitation step exhibits an ultimate detectivity of 2 to 3×10^{-12} gm. If provision is made for analytic recovery during the extraction and concentration phases, the practical ultimate detectivity is taken to be 5×10^{-12} gm. This latter, practical detection limit, will be used in what follows.

Air Stream Analyses--

It is proposed that the primary monitoring point in the incineration system be the emergent stack. Air stream analysis will be accomplished with a full EPA Method Five sampling procedure. The (heated) sampler probe will be operated along two mutually perpendicular traverses with full provision for isokinetic sampling. The impinger train will utilize a glass cyclone and .045 micron glass fiber filter assembly followed by the conventional four-bottle impinger train. The non-particulate impinger solution (confined to the first two impingers) will be 1.0 N NaOH in deionized distilled water. Drying of the gas stream before metering will be accomplished by indicator Drierite(R). The metering equipment will be the RAC stacksampler assembly.

As an additional safety feature, in order to produce essentially real time analyses, the first of the triplicate gas stream samples will be taken with the RAC impinger train modified so as to introduce a small cartridge packed with 10 to 20 gm of uncoated, washed and heat activated Chromosorb 101 absorbent interposed between the 0.45-micron filter and the first impinger bottle. Although this method does not have the force of extensive use, it does offer the great convenience that subsequent to sampling, the cartridge may be removed, the adsorbed chloro carbons removed by hexane washing and immediately analyzed by chromatography. This method has been shown to be applicable for chlorinated hydrocarbons to levels of the order of 15 ppt(*)

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*Mann, J. B., Enos, H. F., Gonzales, J., and Thompson, J. F. Environ. Sci. and Techno., 8, 584 (1974).

(2×10^{-8} gm/m^3) and will be used to get a quick check of the levels of Kepone and also of the principal chlorinated hydrocarbons (hexachlorobenzene, for example)** in the exhaust stream.

If the observed levels are acceptable, then the test will be continued for sufficient time to allow two additional samples to be collected by the more traditional NaOH impinger train.

Air stream sample volume -- As suggested above, the criterion advanced for the distribution between a successful and an unsuccessful test is a Kepone level of not more than 1×10^{-6} gm/m^3 (at stack temperature). The analytical method used for Kepone (see Section 7) is found to have an absolute detection limit $\sim 5 \times 10^{-12}$ gm of Kepone. Since the sample extraction procedure results in a final concentrated sample volume of 0.5 cm^3 and the normal injection volume is 10 λ (10^{-2} cm^3), it is then necessary to collect a total of 2.5×10^{-10} gm Kepone from the sampled gas stream Thus, processing a 1 m^3 gas sample ($\sim$ 0.8 m^3 at box temperature) should yield a total Kepone sample of the order of 40,000 times the detection limit if the level in the gas stream were at the criterion level of 1×10^{-6} gm/m^3. To put this in a slightly different way, the detection limit is 0.0025 percent of the criterion level.

Other Emergent Stream Samples --

In addition to the primary samples (the stack gases) it will be appropriate to also sample the following on a routine basis:

- The emergent quench water
- The emergent scrubber water
- The ash from the kiln

Additional samples -- It will be necessary to sample all charges to the kiln before the pyrolysis of those samples. In addition, background analyses will be made of the feed water and of any other material admitted to the furnace system. Further, environmental samples from within the prototype facility will be analyzed on the completion of the experimental program - this to aid in any clean up that may be required.

Analytical Method --

Initial sample preparation -- Non-aqueous samples, if they are organic in nature, are first macerated with an equal weight of isopropanol and then with benzene and anhydrous sodium sulfate. After being allowed to equilibrate for 12 hr, the filtered extract is evaporated to dryness by impinging a stream of purified air on the surface of the liquid. The resulting residue is treated in a manner similar to inorganic specimens.

The dried residue or inorganic matter is transferred to a separatory

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**Duvall, D. S., and Rubey, W. A. Private Communication.

funnel with small volumes of N-hexane to make a total volume of 100 ml to which is added 25 ml 1:1 oleum mixture. Shake vigorously, allow layers to separate and discard the lower layer. Repeat the process several times, finally washing hexane layer with 10 ml concentrated sulfuric acid, followed by 5 ml water. Discard all washings.

Extract the dried hexane layer with 100 ml 0.1 M sodium hydroxide three times, combining the aqueous sodium hydroxide extracts in a 500 ml separatory funnel.

Analysis of NaOH solution of Kepone -- Add few drops of phenolphthalein solution to the aqueous extracts in the 500 ml separatory funnel. Add 9M sulfuric acid until the end point (colorless) is reached. Add a few ml of 9M sulfuric acid to insure an acidic solution. Extract this acidified solution with 150 ml of benzene. After the phases have equilibrated, draw off the lower (aqueous) phase and discard.

Filter the benzene through a bed of anhydrous, granular Na_2SO_4 into a 300 ml flask. Wash both the funnel and the filter bed with benzene and washings added to the flask. Evaporate the extract on a steam bath under a stream of nitrogen until fumes remain. After cooling, and the vapors condense, wash the walls of the flask with ethyl ether. Transfer quantitatively to a graduated cylinder with small portions of ether. Evaporate the solvent on a steam bath under a stream of nitrogen to approximately 0.3 ml. Determine the exact volume. Transfer the concentrate to a small stoppered vial and freeze until analysis.

The final step involves the injection of a 5 to 10 μ aliquot of the concentrate into an Electron Capture G.C. System with the following characteristics:

Electron Capture detector using Ni^{63}
Column of either
    10% DC-200 + 15% QF-1 or
    1.5% OV-17 + 1.95% QF-1 on 100/120 GCQ
    Carrier gas: 95% Argon + 5% methane
    Gas flow: 4 - 55 ml/run
    Injection port: $200^{\circ}C$
    Oven temp (isothermal): $220^{\circ}C$
    Detector temp: $250^{\circ}C$

A typical chromatogram derived in our laboratories of Kepone indicates a retention time of the order of 10.6 min and an ultimate detectivity on the order of 2.5×10^{-12} gm.

Kepone combustion products -- Although the full spectrum of possible intermediate combustion productions of Kepone has not been determined, it is known that hexachlorobenzene is one of the principal products.

Operating Variables --

In addition to Kepone and chlorinated hydrocarbon analysis of the discharge streams from the incinerator, it will also be necessary to collect the following parametric data:

Sludge feed rate
Kepone feed rate
Kiln temperature
Air and gas flow to the kiln burner
Flow of gases from the kiln
Analysis of gases from the kiln
Pressure in the kiln
Temperature in incinerator
Air and gas flows to incinerator burners
Auxiliary gas flow to the incinerator
Effluent gas flow from the incinerator
Quench liquid flows
Make-up water flow to quench
Temperature of stack gases
Scrubbing liquid flow
Caustic addition flow
Purge brine flow from scrubber
Temperature of gases from quench
Pressure of gases from quench
Flow of gases in the stack
Temperature of scrubbing liquid

Proposed Schedule

In the interest of efficiency and to minimize furnace operation times, it is proposed that the study be carried out on an essentially two-shift basis: the daytime devoted to the actual combustion runs and the necessary sampling and the night shift devoted to analysis. The field operations will take the following form:

Week 1

Mon./Tues.	1st injection run; sampling/analyses
Wed./Thurs.	2nd injection run; sampling/analyses
Fri./Sat.	3rd injection run; sampling/analyses

Week 2

Tues./Wed.	4th injection run; sampling/analyses
Thurs./Fri.	5th injection run; sampling/analyses

Week 3

Monday	6th injection run; sampling/analyses

Tuesday	Sludge blank run; Sampling/analyses
Wednesday	Hopewell contaminated sludge sampling/analyses
Thursday	Hopewell contaminated sludge sampling/analyses
Friday	Toledo sludge @ 25% Kepone

Week 4

Monday	Toledo sludge @ 25% Kepone
Tuesday	Toledo sludge @ 50% Kepone
Wednesday	Toledo sludge @ 50% Kepone
Thursday	River sediments
Friday	Recap meeting

Week 5

Monday/Friday	Clean up

Residual Disposal

Except, of course, for emissions to the air any material at the end of the test that cannot be disposed of locally due to public health considerations will be transported to Hopewell, Virginia, for disposal.

Emissions to the Air --

As described previously all air emissions will be constantly monitored. The test program is designed to ensure that the level of Kepone if emitted will not reach the maximum level of 1×10^{-6} gm/m^3 at stack temperature.

Solids and Liquids --

Ashes and scrubber liquor will result during all incineration tests of sludge. When pure Kepone is incinerated, there will be no ashes.

All liquid and solid residues resulting from the incineration tests will be either re-incinerated or repackaged and transported to Virginia for disposal.

Laboratory Residuals --

Same procedures as Solids and Liquids

Spillage and Clean-Up--

Minor spills should they occur will be mopped up. Liquid will be transferred to the liquid retention tank and rags, etc., will be stored in a Contaminated-Material Container (CMC). Major spills should they occur will be absorbed in dry compound. The sweepings will again be placed in the CMC.

All disposable gloves, etc., will be placed in the CMC.

Testing program will include incineration of the CMC as part of the clean-up after incineration tests.

Equipment Clean-Up --

After the incineration test program is complete all equipment and residuals contaminated during the process will be either incinerated or cleaned with NaOH (which will put Kepone in a solution) for ultimate disposal.

The equipment to be cleaned includes the following:

Moyno pump (stator and rotor) used to pump the sludge
Feed pipe and mixing tank for the sludge
Rotary kiln
Duct between the rotary kiln and the afterburner
Scrubber tower and piping
Quench and pumps
Brine retention tanks
Safety equipment (gloves, respirators, clothing, etc.)

Safety and Hygiene

The prime consideration during the incineration test will be to protect the personnel, the environment, and the public from being exposed to this compound. To ensure safety the measures included in this section will be followed in addition to those normally used.

Incineration Test --

The personnel at the testing facility are experienced with the handling and burning of toxic and other dangerous chemicals. Such work has been done and safety procedures are already established.

In order to inform the operating and management personnel about Kepone and recommend handling procedures a medical briefing will be conducted by personnel from the Commonwealth of Virginia, Department of Health at the site prior to the incineration test program.

Only operating and management personnel directly involved with the incineration test operation will be allowed in either the incineration test or laboratory areas. Before and after the incineration test they will be subjected to blood tests to determine if any residual Kepone exists.

Isolation will be accomplished by organizing the incineration test area and physical facilities such that only those persons whose duties necessitate their presence are in areas where hazardous materials are handled. Preparation for incineration tests and equipment readiness will be accomplished prior to handling of Kepone or Kepone bearing materials or their introduction into the incineration system.

Kepone and Kepone bearing materials will be handled only in closed systems or in the isolated area designated for mixing, feeding and storage. The only normal entrance and egress to this area will be through a shower area with a change of clothes required upon entry and a shower and change of clothes required prior to leaving the area.

There will be an emergency exit for life safety from this area and a viewing port to allow observation during the handling procedures.

The control and operation of the incineration and pollution control equipment will take place in the designated area separated from the mixing, feeding and kiln areas by barriers preventing air and other materials movement.

Equipment and surfaces in the incineration test area shall be covered with strippable coverings or plastic film wherever practical. All floors in the incineration test area will be sealed with either paint or resin sealants to facilitate cleaning.

Areas within the incineration test area subject to spillage shall be curbed to contain any foreseeable leakage.

All personnel who have entered the incineration test area for any purpose will shower before leaving the premises and will leave their clothing including socks and underwear which was worn within the incineration test area in designated lockers within the contaminated change room. At the end of the incineration test period this clothing will be incinerated. Street clothing will be stored in the clean locker room.

Personnel protective equipment worn will be that which is deemed suitable for the job and conditions at hand by the Industrial Hygienists assigned to the incineration test. A list of suitable equipment is attached as Table D-1.

TABLE D-1 PERSONAL PROTECTIVE EQUIPMENT

Safety glasses with side shields
Goggles - Sellstrom 882 Fog-free lens
Respirators - Comfo II GMP Type, Part No. 448848, MSA
Cartridges (pesticide) GMP Type No. 448847, MSA
High gauntlet gloves, MSA, Python Neoprene 37994
Paper suits, Edmont-Wilson 55-510
Rain gear, Edmont-Wilson, Coat & Hood 65-110, Bib Overalls 65-120
Boots-Servus, Neoprene 11901, steel toe
Disposable boots (plastic)
Paper boots (paper)
Paper headcover
Disposable towels - obtain locally
Plastic bags (large) - obtain locally
Bag rack - obtain locally
Utility gloves, MSA, 37643 flexible plastic gloves

The above are examples of equipment needed and does not constitute an endorsement of the products. Substitution can be made on an equivalent basis.

The actual number of pieces and sizes of equipment will be determined by Surface Combustion and will be reviewed at the meeting on September 21, 1976, in Cincinnati, Ohio.

Pure Kepone Transport and Handling --

Since all the Kepone on the incineration test site will be in a liquid solution, Kepone in the atmosphere (as with dust in the pure powder form) will be minimized if not eliminated. This means that the exposure to the operating personnel will be the absolute minimum.

The Kepone will be packaged and transported as previously described. Kepone containers will be opened by authorized personnel wearing protective clothing including respirator and goggles. Containers will only be opened in the incineration test area or the laboratory.

Kepone spills are not anticipated. If there are any, they will be handled carefully and the clean up material disposed by the procedures described in the section on residuals.

Air Sampling and Laboratory Personnel --

Air sampling personnel and laboratory personnel will attend the medical briefing and will undergo blood tests before and after the incineration test program. During all times of operation, personnel will wear protective clothing, goggles and hard hats. Whenever Kepone is handled, respirators will be used.

Visitors --

No visitors will be allowed in the incineration test area and laboratory areas.

During the incineration test, visitors will be able to observe the incineration test operation via closed circuit TV from a monitor in the conference room. A register will be kept of all visitors entering and leaving the conference room.

Publicity and Communication

Publicity and communication with regard to the incineration test will be controlled by the Incineration Test Authority (ITA). Under the direction of the ITA, the Incineration Test Management Group will perform the following activities:

Escort visitors and inform them of the incineration test and sampling operation.

Interface with regulatory agencies.

Coordinate the documentation effort.

Press Release --

Press releases will be authorized by the Incineration Test Authority and cleared through the Toledo Public Information Director.

Prior to the incineration test, Surface Division, Midland-Ross is planning the following pre-incineration test news releases through the Toledo PID:

30 days prior to test - general newspaper article, science oriented, on Surface Division work in hazardous waste disposal.

15 days before test - general newspaper article, business oriented, on Surface Division's new business venture in hazardous waste disposal.

After Kepone contract award and prior to incineration test - newspaper article to announce R & D program to demonstrate controlled incineration technology for Kepone disposal.

During and after the incineration test, Surface Division is planning the following news releases with the approval of the Incineration Test Authority:

In process - announcement that Surface Division engineers are working with small quantities of Kepone.

30 days after incineration test - Kepone incineration success story:

1977 - articles in technical journals.

Documentation

The Incineration Test Management Group will be in charge of documentation of the incineration test program and results.

The Operations Manager will report on the technical aspects of the incineration test, the equipment used, and the residuals.

The Sampling and Testing Manager will report on the test results, on the air samples, residuals and Kepone inventory.

The Project Manager will write a summary report (including other aspects, such as transportation, safety and visitors).

During the incineration test, daily oral reports will be made to the Incineration Test Authority. All day-to-day decisions will be based on these reports. Distribution of the data will be controlled by the Incineration Test Authority.

The Project Manager will prepare the final report for submission to the Incineration Test Authority for submission ultimately to the Virginia Kepone Task Force.

APPENDIX E. FURNACE AND INCINERATOR SYSTEM DATA

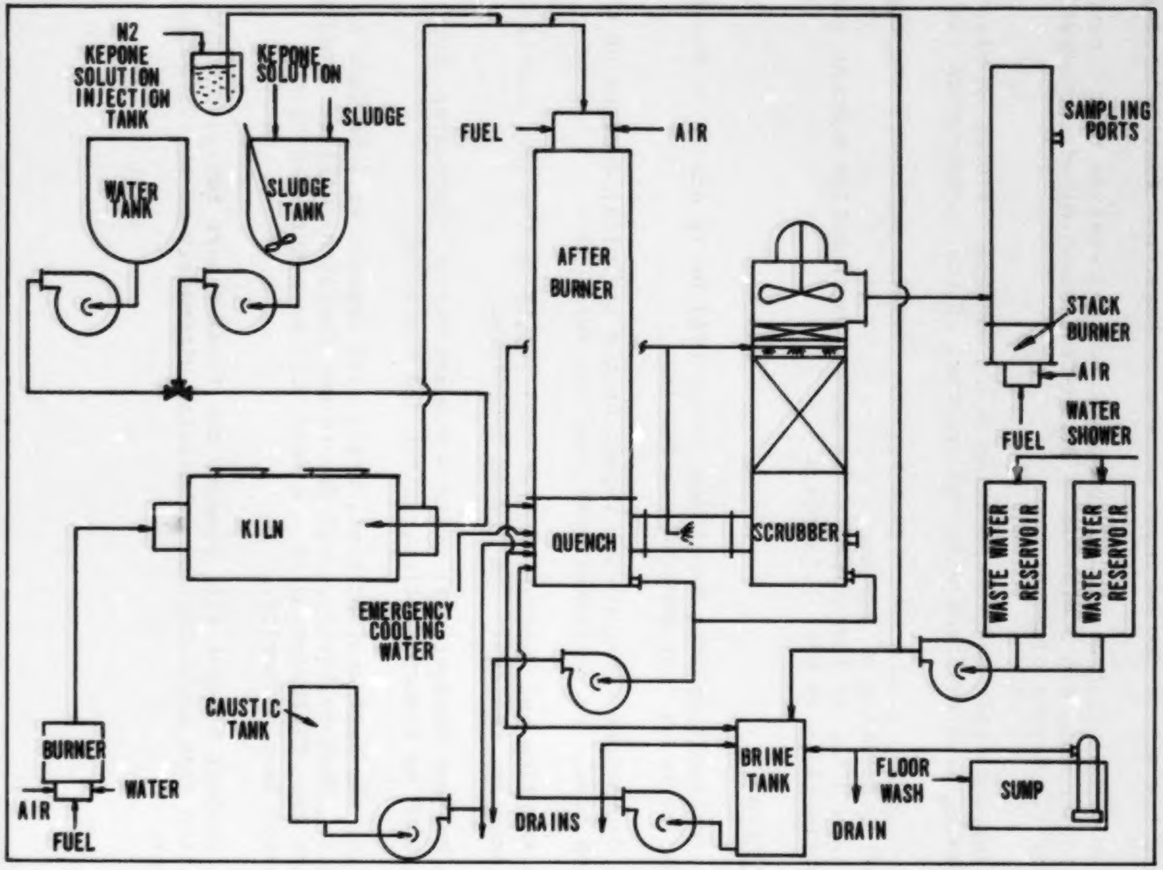
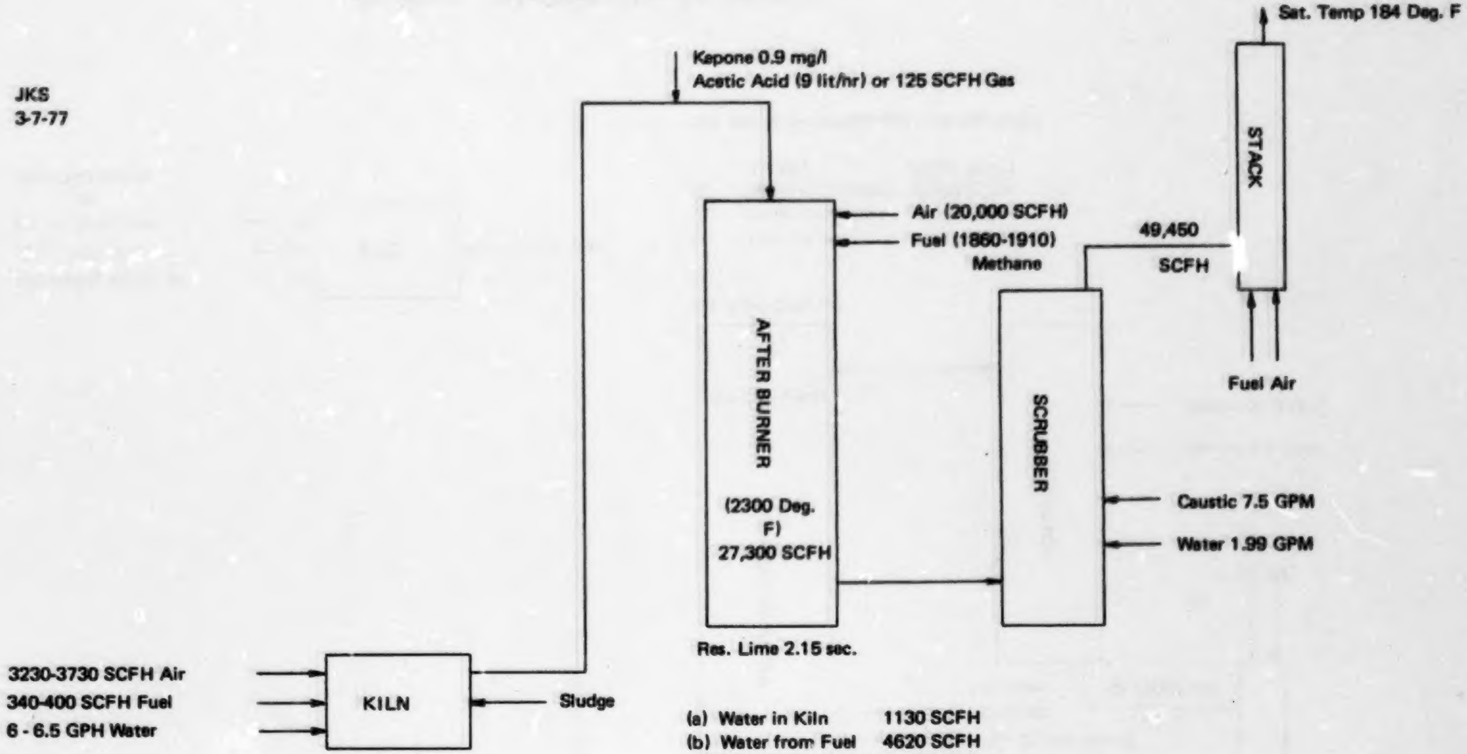

N2
KEPONE SOLUTION INJECTION TANK
KEPONE SOLUTION
SLUDGE
WATER TANK
SLUDGE TANK
FUEL
AIR
AFTER BURNER
SAMPLING PORTS
STACK BURNER
AIR
FUEL
WATER SHOWER
WASTE WATER RESERVOIR
WASTE WATER RESERVOIR
KILN
QUENCH
SCRUBBER
EMERGENCY COOLING WATER
CAUSTIC TANK
BURNER
AIR
WATER
FUEL
DRAINS
BRINE TANK
FLOOR WASH
SUMP
DRAIN

FIGURE E-1: KEPONE INCINERATION SYSTEM SCHEMATIC

JKS
3-7-77

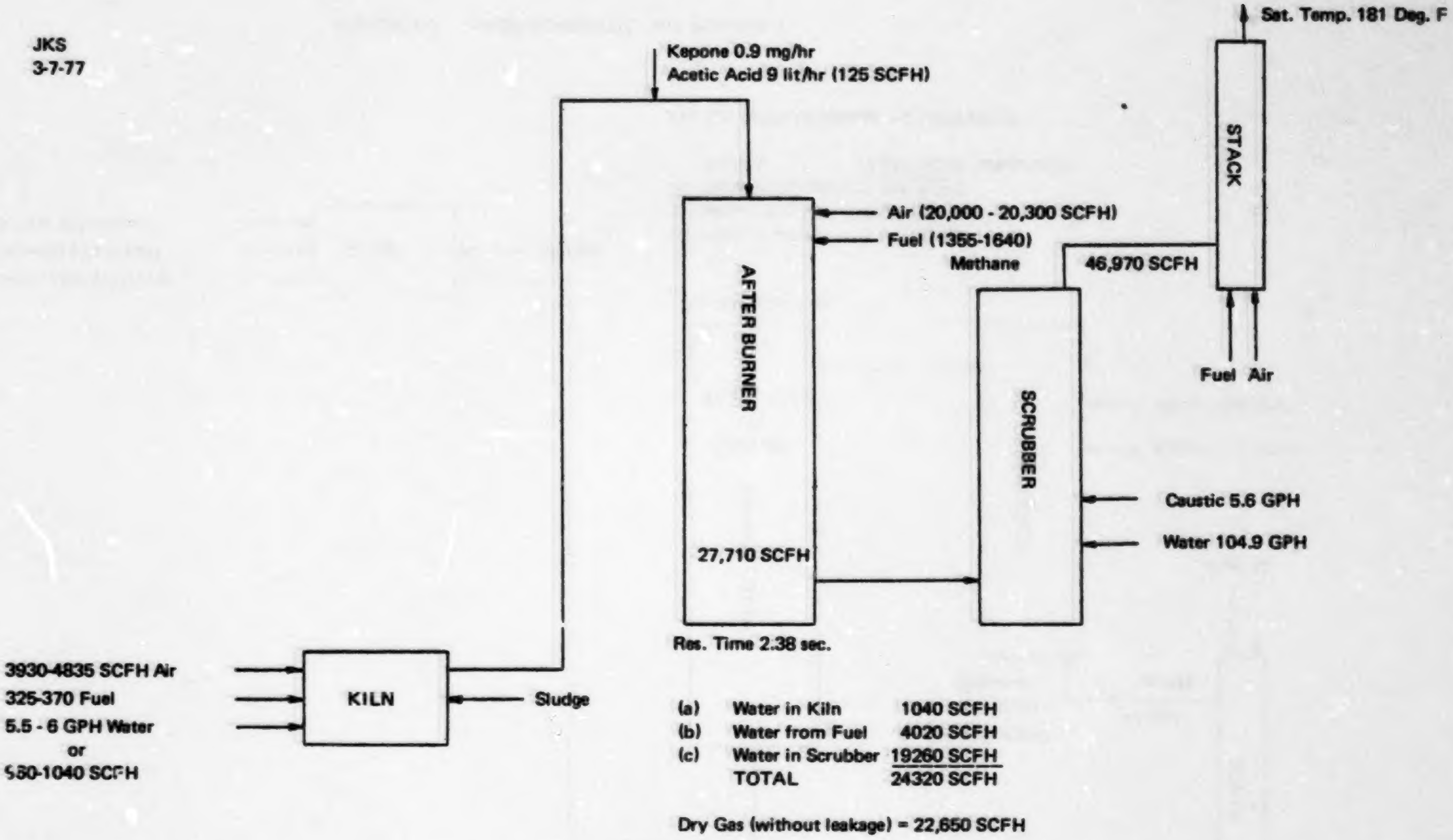

Sat. Temp 184 Deg. F
Kepone 0.9 mg/l
Acetic Acid (9 lit/hr) or 125 SCFH Gas
STACK
Air (20,000 SCFH)
Fuel (1860-1910)
Methane
49,450
SCFH
Fuel Air
AFTER BURNER
(2300 Deg. F)
27,300 SCFH
SCRUBBER
Caustic 7.5 GPM
Water 1.99 GPM
3230-3730 SCFH Air
340-400 SCFH Fuel
6 - 6.5 GPH Water
KILN
Sludge

Res. Lime 2.15 sec.

(a) Water in Kiln	1130 SCFH
(b) Water from Fuel	4620 SCFH
(c) Water in Scrubber	22,100 SCFH
TOTAL	27,850 SCFH (Maximum)

Dry Gas (without leakage) = 21,600 SCFH

FIGURE E-2 FLOW SCHEMATIC - KIT RUN NO. 1


JKS
3-7-77
Kepone 0.9 mg/hr
Acetic Acid 9 lit/hr (125 SCFH)
Sat. Temp. 181 Deg. F
STACK
Air (20,000 - 20,300 SCFH)
Fuel (1355-1640)
Methane
46,970 SCFH
Fuel
Air
AFTER BURNER
SCRUBBER
Caustic 5.6 GPH
Water 104.9 GPH
27,710 SCFH
3930-4835 SCFH Air
325-370 Fuel
5.5 - 6 GPH Water
or
550-1040 SCFH
KILN
Sludge

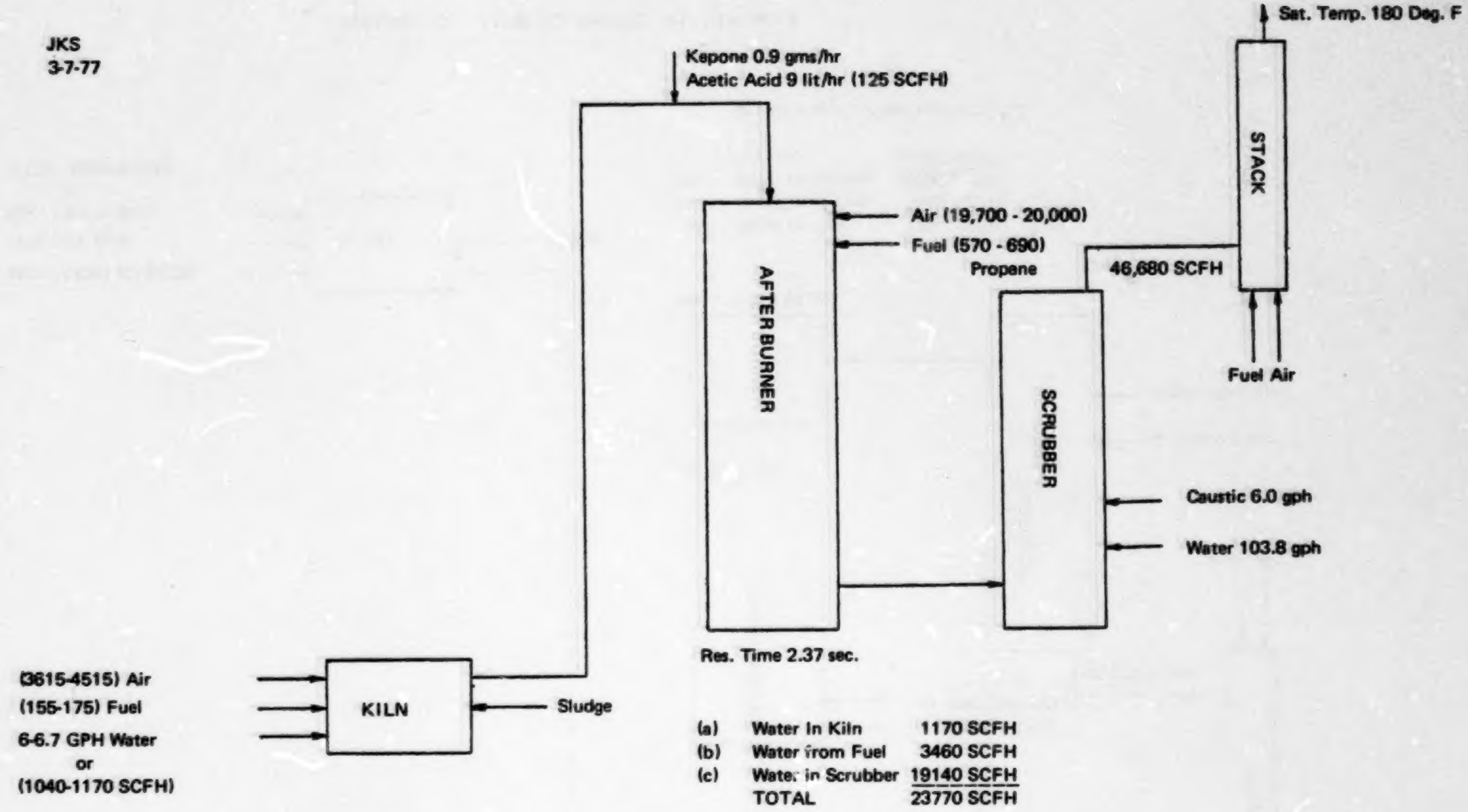
Res. Time 2.38 sec.

(a)	Water in Kiln	1040 SCFH
(b)	Water from Fuel	4020 SCFH
(c)	Water in Scrubber	19260 SCFH
	TOTAL	24320 SCFH

Dry Gas (without leakage) = 22,650 SCFH

FIGURE E-3 FLOW SCHEMATIC - KIT RUN NO. 2

JKS
3-7-77


Sat. Temp. 180 Deg. F
Kepone 0.9 gms/hr
Acetic Acid 9 lit/hr (125 SCFH)
STACK
Air (19,700 - 20,000)
Fuel (570 - 690)
Propene
46,680 SCFH
AFTER BURNER
SCRUBBER
Fuel Air
Caustic 6.0 gph
Water 103.8 gph
(3615-4515) Air
(155-175) Fuel
6-6.7 GPH Water
or
(1040-1170 SCFH)
KILN
Sludge

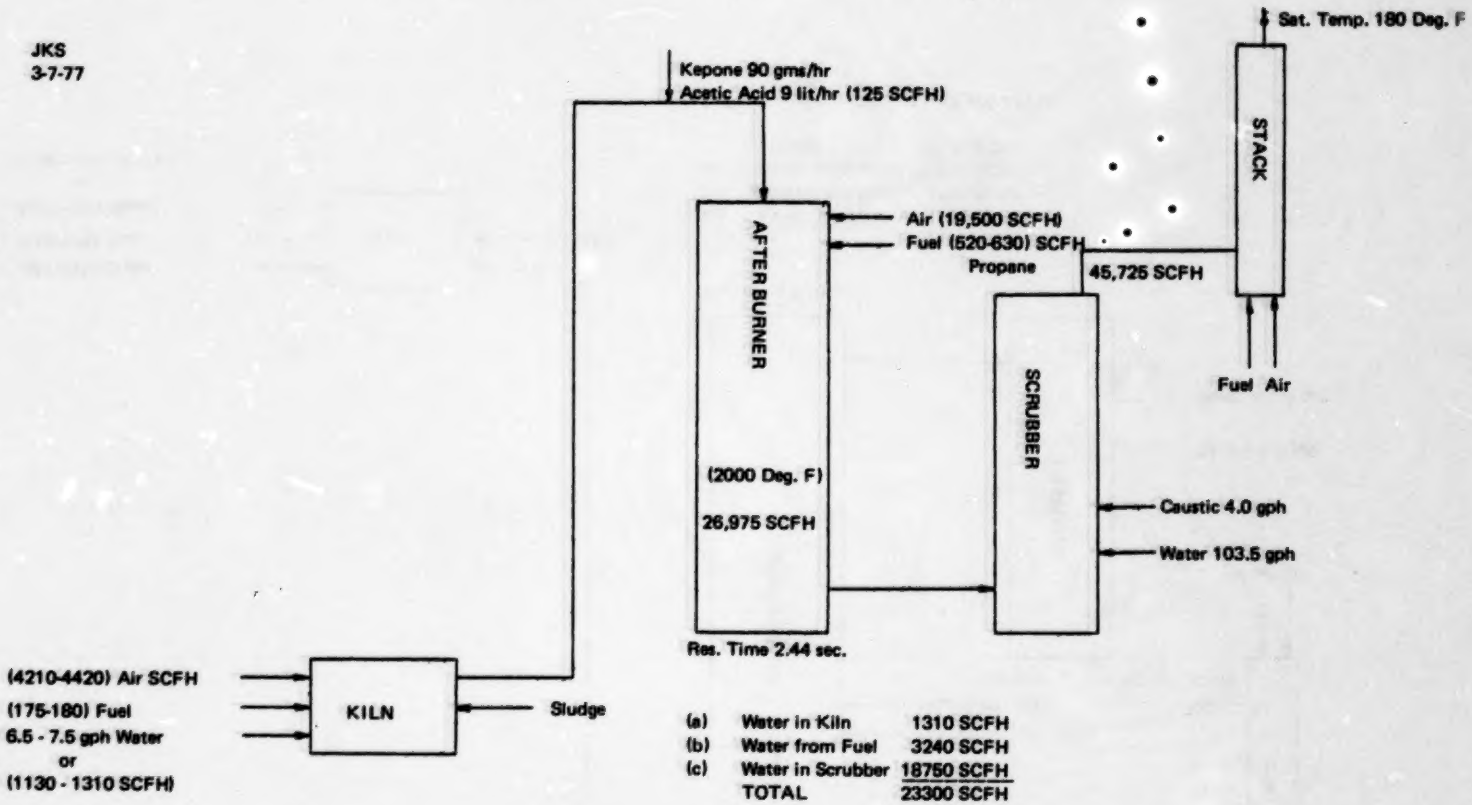
Res. Time 2.37 sec.

(a)	Water In Kiln	1170 SCFH
(b)	Water from Fuel	3460 SCFH
(c)	Water in Scrubber	19140 SCFH
	TOTAL	23770 SCFH

Dry Gas (without leakage) = 32,910 SCFH

FIGURE E-4 FLOW SCHEMATIC - KIT RUN NO. 3

JKS
3-7-77

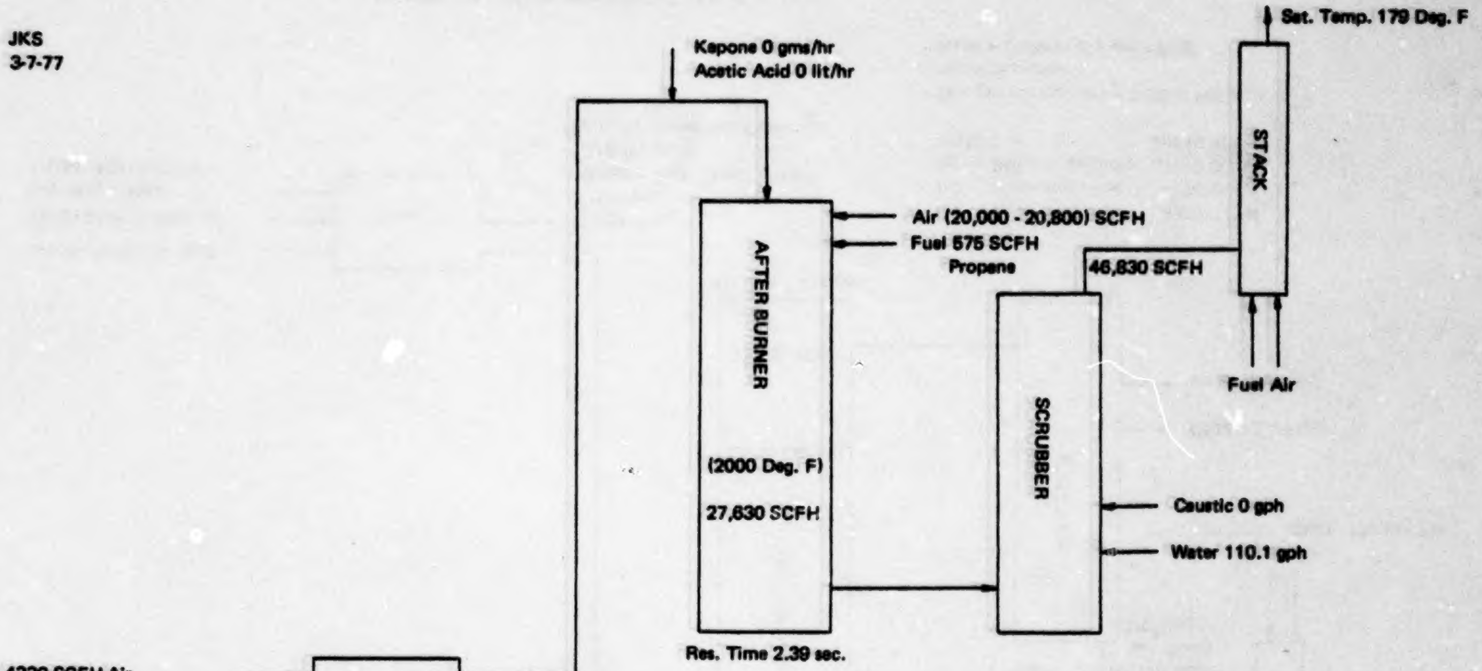

Sat. Temp. 180 Deg. F
Kepone 90 gms/hr
Acetic Acid 9 lit/hr (125 SCFH)
STACK
AFTER BURNER
Air (19,500 SCFH)
Fuel (520-630) SCFH
Propane
45,725 SCFH
Fuel
Air
SCRUBBER
(2000 Deg. F)
26,975 SCFH
Caustic 4.0 gph
Water 103.5 gph
Res. Time 2.44 sec.
(4210-4420) Air SCFH
(175-180) Fuel
6.5 - 7.5 gph Water
or
(1130 - 1310 SCFH)
KILN
Sludge

(a)	Water in Kiln	1310 SCFH
(b)	Water from Fuel	3240 SCFH
(c)	Water in Scrubber	18750 SCFH
	TOTAL	23300 SCFH

Dry Gas (without leakage) = 22,425

FIGURE E-5 FLOW SCHEMATIC - KIT RUN NO. 4

JKS
3-7-77

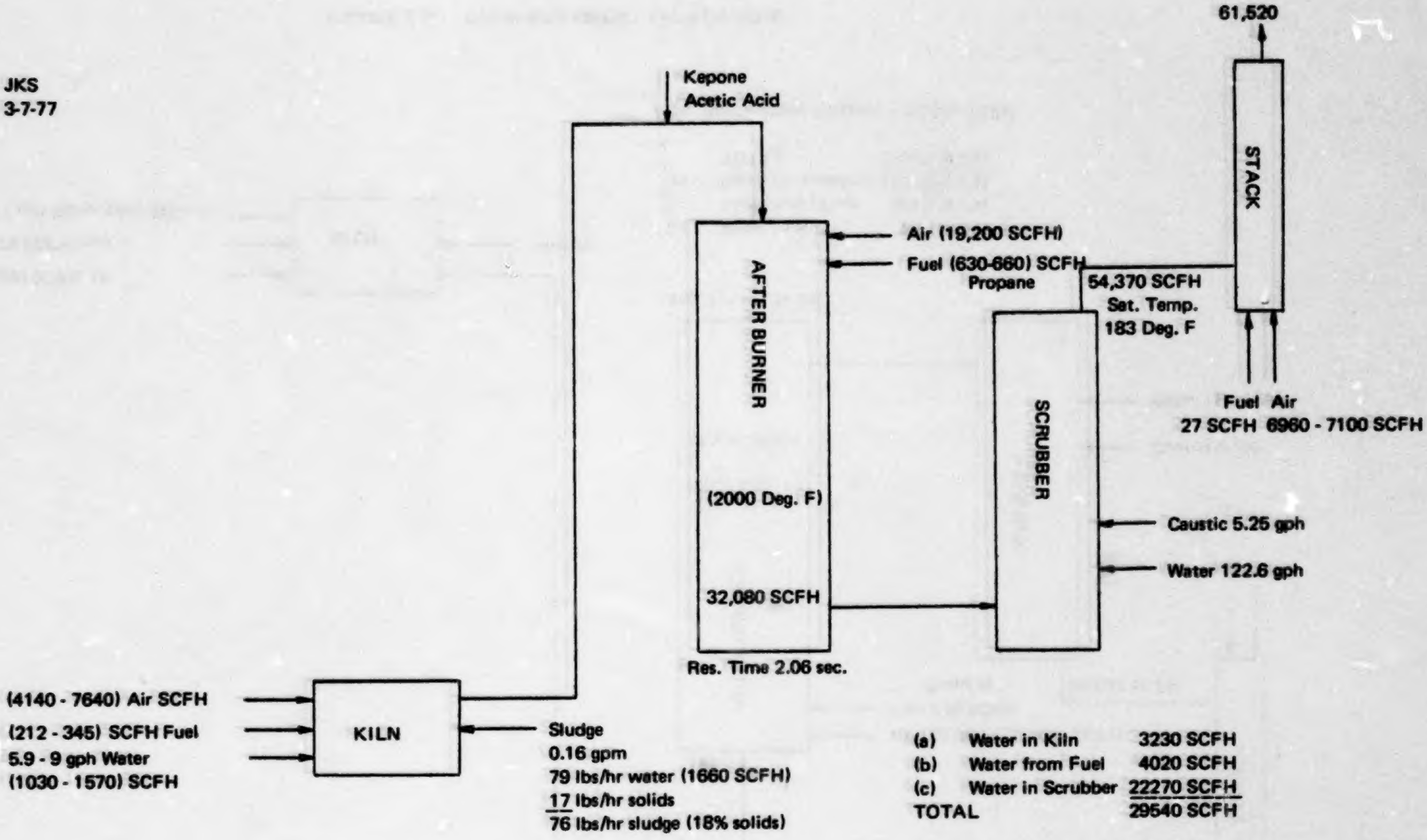

Sat. Temp. 179 Deg. F
Kapone 0 gms/hr
Acetic Acid 0 lit/hr
STACK
Air (20,000 - 20,800) SCFH
Fuel 575 SCFH
Propane
46,830 SCFH
AFTER BURNER
(2000 Deg. F)
27,630 SCFH
SCRUBBER
Fuel Air
Caustic 0 gph
Water 110.1 gph
4330 SCFH Air
178 SCFH Fuel
5.7 gph Water (990 SCFH)
KILN
Sludge
Res. Time 2.39 sec.

(a)	Water in Kiln	990 SCFH
(b)	Water from Fuel	3010 SCFH
(c)	Water in Scrubber	19200 SCFH
	TOTAL	23200 SCFH

Dry Gas (without leakage) = 23,630 SCFH

FIGURE E-6 FLOW SCHEMATIC - KIT RUN NO. 5

JKS
3-7-77

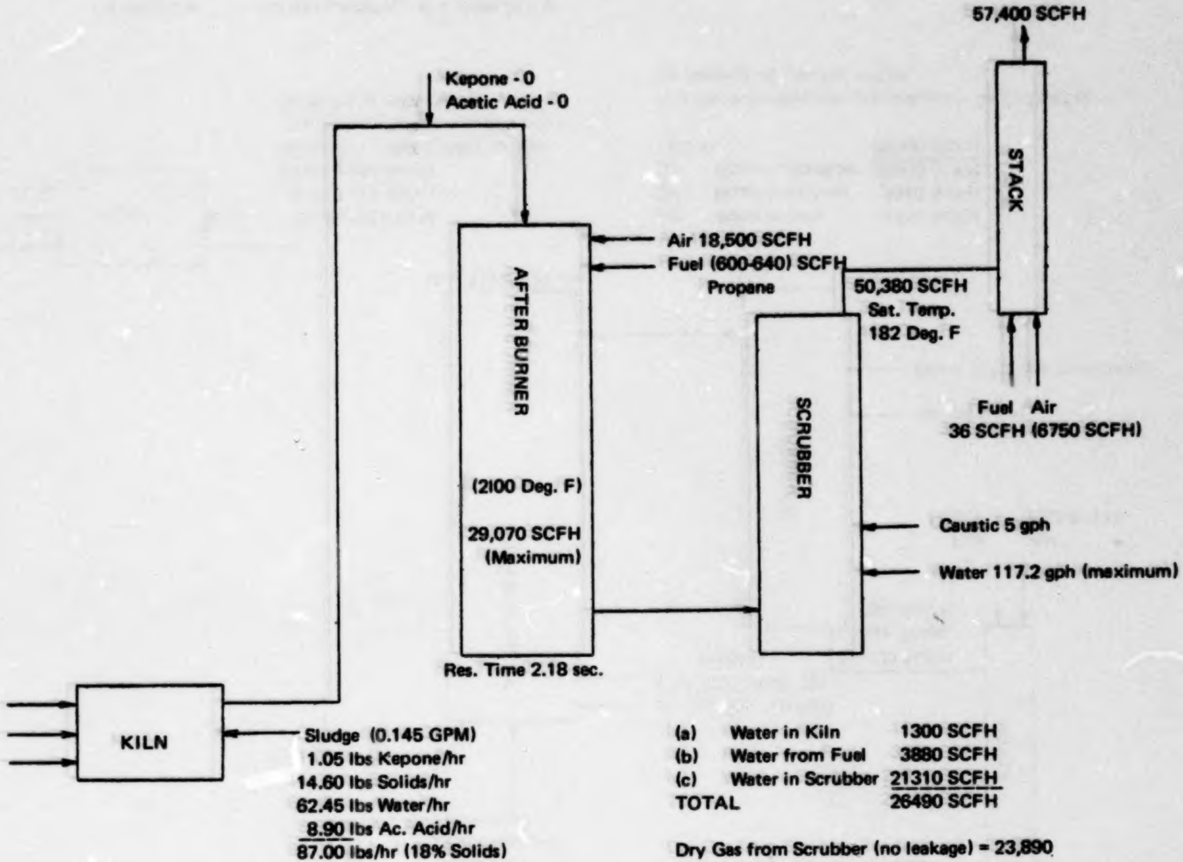

61,520
STACK
Kepone
Acetic Acid
Air (19,200 SCFH)
Fuel (630-660) SCFH
Propane
54,370 SCFH
Sat. Temp.
183 Deg. F
Fuel Air
27 SCFH 6960 - 7100 SCFH
AFTER BURNER
(2000 Deg. F)
32,080 SCFH
Res. Time 2.06 sec.
SCRUBBER
Caustic 5.25 gph
Water 122.6 gph
(4140 - 7640) Air SCFH
(212 - 345) SCFH Fuel
5.9 - 9 gph Water
(1030 - 1570) SCFH
KILN
Sludge
0.16 gpm
79 lbs/hr water (1660 SCFH)
17 lbs/hr solids
76 lbs/hr sludge (18% solids)

(a)	Water in Kiln	3230 SCFH
(b)	Water from Fuel	4020 SCFH
(c)	Water in Scrubber	22270 SCFH
TOTAL		29540 SCFH

Dry Gas (no leakage) = 24,830 SCFH
out of Scrubber
lbs of H_2O/lb of dry gas = 0.76

FIGURE E-7 FLOW SCHEMATIC - KIT RUN NO. 6

JKS
3-7-77

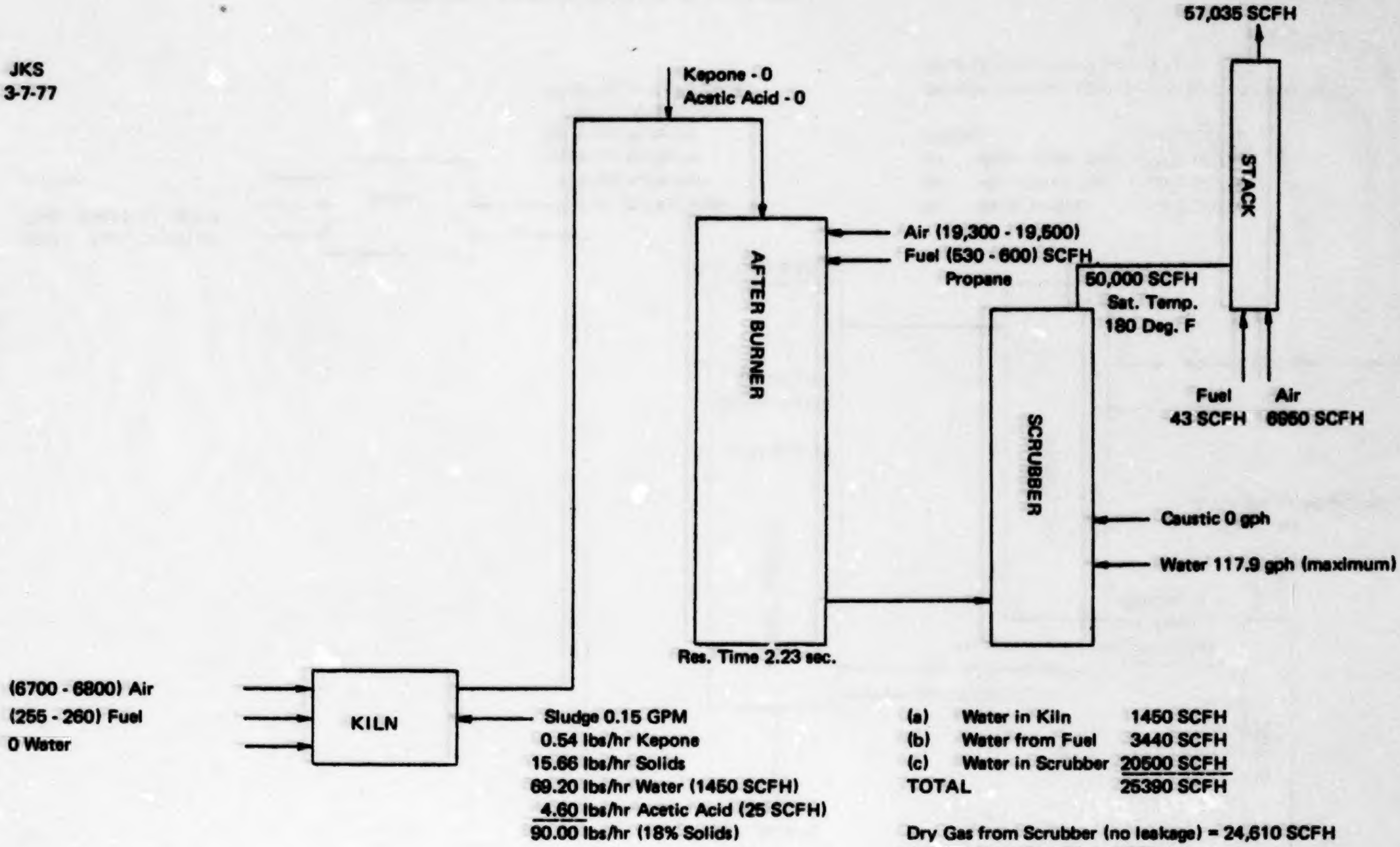

57,400 SCFH
Kepone - 0
Acetic Acid - 0
STACK
Air 18,500 SCFH
Fuel (600-640) SCFH
Propane
50,380 SCFH
Sat. Temp.
182 Deg. F
AFTER BURNER
(2100 Deg. F)
29,070 SCFH
(Maximum)
Res. Time 2.18 sec.
SCRUBBER
Fuel Air
36 SCFH (6750 SCFH)
Caustic 5 gph
Water 117.2 gph (maximum)
(6510 - 7265) SCFH Air
(295 - 330) Fuel SCFH
0 Water
KILN
Sludge (0.145 GPM)
1.05 lbs Kepone/hr
14.60 lbs Solids/hr
62.45 lbs Water/hr
8.90 lbs Ac. Acid/hr
87.00 lbs/hr (18% Solids)

(a)	Water in Kiln	1300 SCFH
(b)	Water from Fuel	3880 SCFH
(c)	Water in Scrubber	21310 SCFH
TOTAL		26490 SCFH

Dry Gas from Scrubber (no leakage) = 23,890
lbs of H_2O/lb. of dry gas = 0.71

FIGURE E-8 FLOW SCHEMATIC - KIT RUN NO. 7

JKS
3-7-77

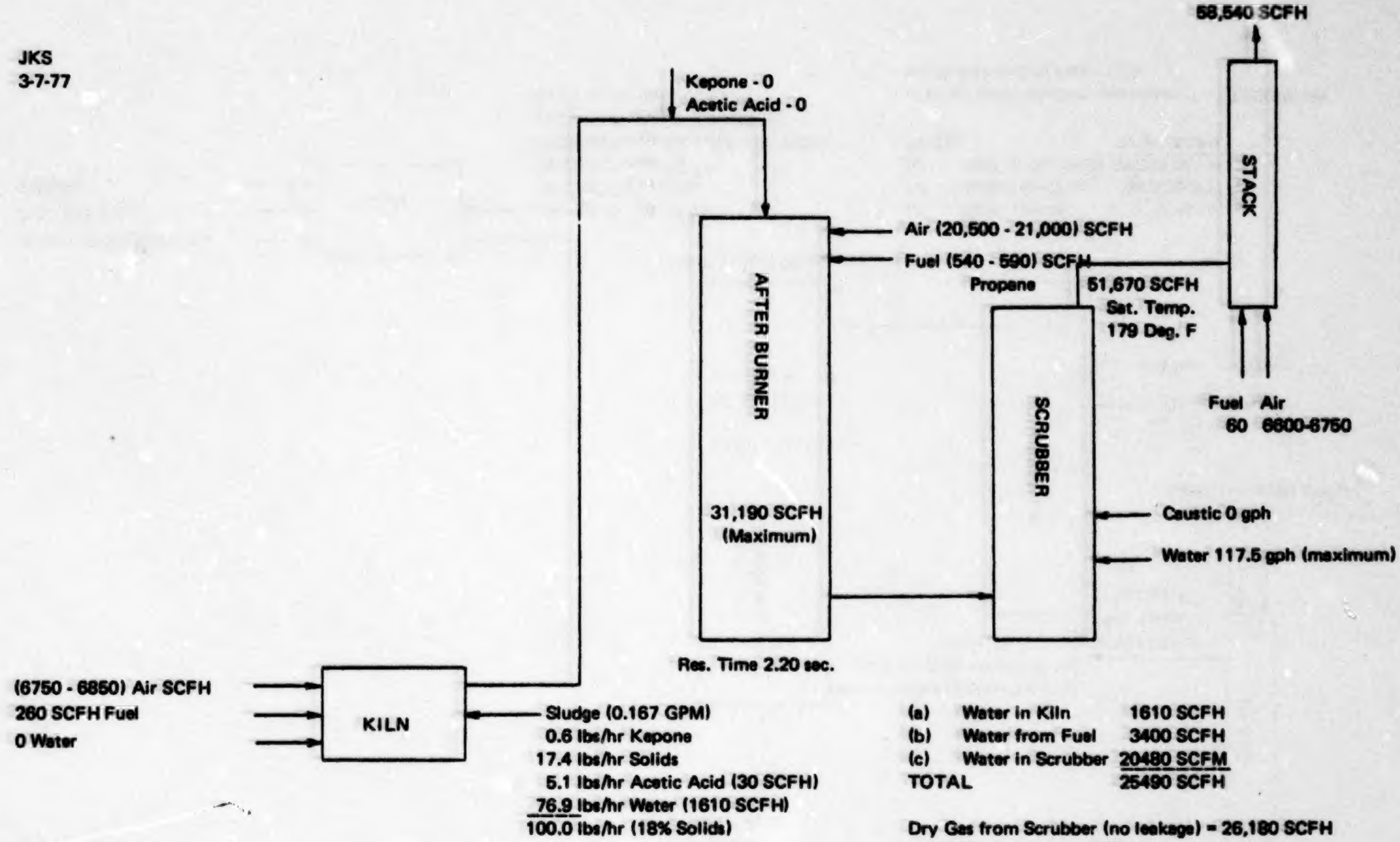

57,035 SCFH
STACK
Kepone - 0
Acetic Acid - 0
AFTER BURNER
Air (19,300 - 19,500)
Fuel (530 - 600) SCFH
Propane
50,000 SCFH
Sat. Temp.
180 Deg. F
Fuel
43 SCFH
Air
6960 SCFH
SCRUBBER
Caustic 0 gph
Water 117.9 gph (maximum)
Res. Time 2.23 sec.
(6700 - 6800) Air
(255 - 260) Fuel
0 Water
KILN
Sludge 0.15 GPM
0.54 lbs/hr Kepone
15.66 lbs/hr Solids
69.20 lbs/hr Water (1450 SCFH)
4.60 lbs/hr Acetic Acid (25 SCFH)
90.00 lbs/hr (18% Solids)

(a)	Water in Kiln	1450 SCFH
(b)	Water from Fuel	3440 SCFH
(c)	Water in Scrubber	20500 SCFH
TOTAL		25390 SCFH

Dry Gas from Scrubber (no leakage) = 24,610 SCFH
lbs Water/lb of Dry Gas = 0.66

FIGURE E-9 FLOW SCHEMATIC - KIT RUN NO. 8

JKS
3-7-77

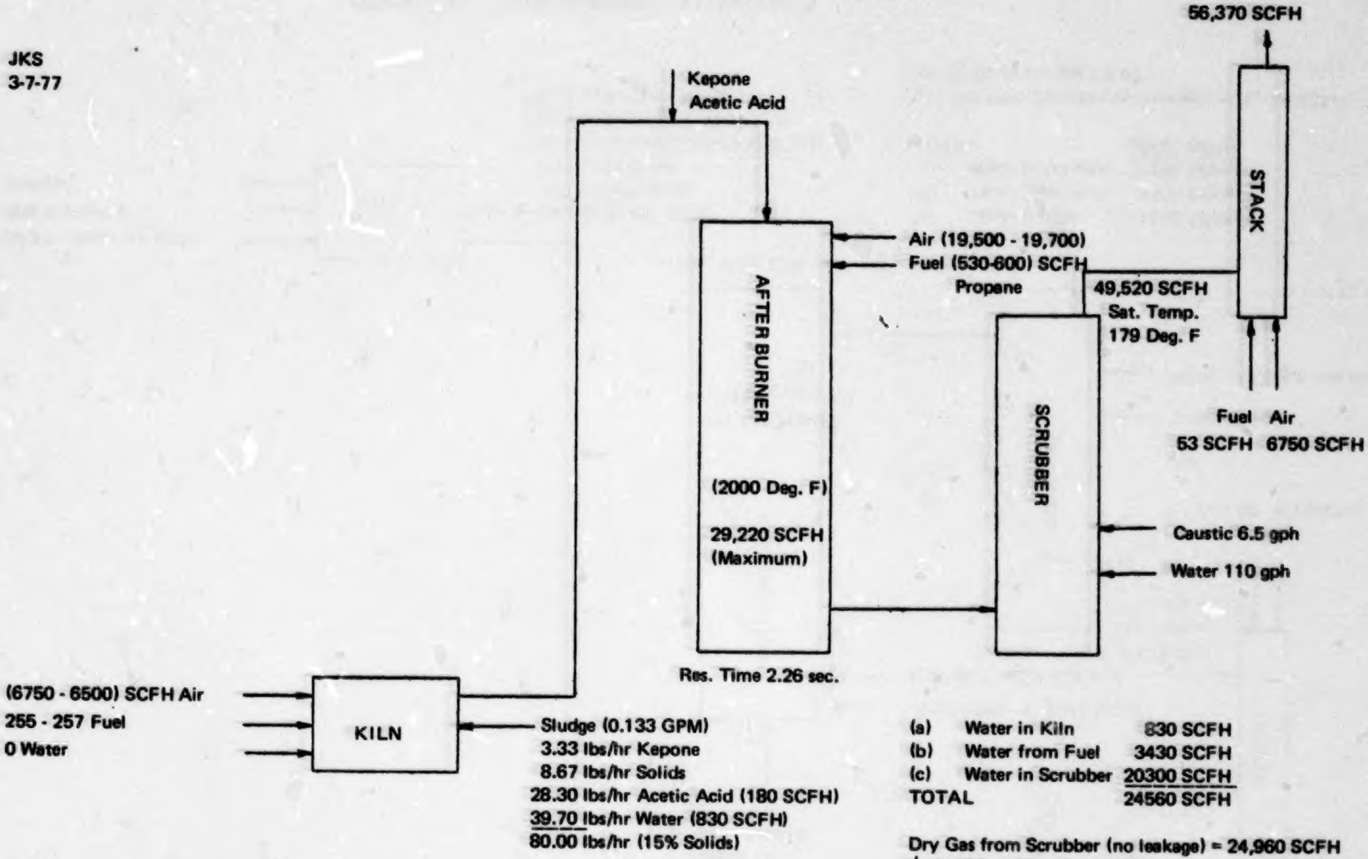

58,540 SCFH
STACK
Kepone - 0
Acetic Acid - 0
AFTER BURNER
Air (20,500 - 21,000) SCFH
Fuel (540 - 590) SCFH
Propane
51,670 SCFH
Sat. Temp.
179 Deg. F
Fuel Air
60 6600-6750
SCRUBBER
31,190 SCFH
(Maximum)
Caustic 0 gph
Water 117.5 gph (maximum)
Res. Time 2.20 sec.
(6750 - 6850) Air SCFH
260 SCFH Fuel
0 Water
KILN
Sludge (0.167 GPM)
0.6 lbs/hr Kepone
17.4 lbs/hr Solids
5.1 lbs/hr Acetic Acid (30 SCFH)
76.9 lbs/hr Water (1610 SCFH)
100.0 lbs/hr (18% Solids)

(a)	Water in Kiln	1610 SCFH
(b)	Water from Fuel	3400 SCFH
(c)	Water in Scrubber	20480 SCFM
TOTAL		25490 SCFH

Dry Gas from Scrubber (no leakage) = 26,180 SCFH
lbs H_2)/lb of dry gas = 0.62

FIGURE E-10 FLOW SCHEMATIC - KIT RUN NO. 9

JKS
3-7-77


56,370 SCFH
Kepone
Acetic Acid
STACK
Air (19,500 - 19,700)
Fuel (530-600) SCFH
Propane
49,520 SCFH
Sat. Temp.
179 Deg. F
AFTER BURNER
SCRUBBER
Fuel
Air
53 SCFH
6750 SCFH
(2000 Deg. F)
29,220 SCFH
(Maximum)
Caustic 6.5 gph
Water 110 gph
Res. Time 2.26 sec.
(6750 - 6500) SCFH Air
255 - 257 Fuel
0 Water
KILN
Sludge (0.133 GPM)
3.33 lbs/hr Kepone
8.67 lbs/hr Solids
28.30 lbs/hr Acetic Acid (180 SCFH)
39.70 lbs/hr Water (830 SCFH)
80.00 lbs/hr (15% Solids)

(a)	Water in Kiln	830 SCFH
(b)	Water from Fuel	3430 SCFH
(c)	Water in Scrubber	20300 SCFH
TOTAL		24560 SCFH

Dry Gas from Scrubber (no leakage) = 24,960 SCFH
lbs H_2O/lb of Dry Gas = 0.62

FIGURE E-11 FLOW SCHEMATIC - KIT RUN NO. 10

TABLE E-1 KIT RUN NO. 1 DATE: 1-14-77

Time Variable	1535	1630	1700	1730	1830	1930	COMMENTS
FUME INCINERATOR							
Incinerator Temp. (Deg. C)	1260	1260	1260	1260	1260	1260	
Total Air Input (SCMH)	560	560	560	560	560	560	
Gas Input @ Pilot No. 1 (SCMH)	8.54	8.54	8.54	8.54	8.54	8.54	Methane
Gas Input at Pilot No. 2 (SCMH)	8.54	8.54	8.54	8.54	8.54	8.54	Methane
Aux. Gas Input (SCMH)	36.40	35.00	—	—	—	—	Methane
Inlet Gas Temp. (Deg. C)	456	459	—	458	411	407	
Stack Flow Rate (SCMH)	—	—	—	—	—	—	
Air in Stack Burner (SCMH)	—	—	—	—	—	—	
Pilot Gas to Stack Burner (SCMH)	—	—	—	—	—	—	
Aux. Gas to Stack Burner (SCMH)	—	—	—	—	—	—	
Stack Temp. (Deg. C)	—	—	—	—	—	—	
% Oxygen in Stack	3.0	4.5	—	—	—	—	
KILN							
Burner Gas Temp. (Deg. C)	1066	1016	—	1024	1015	1016	
Gas Discharge Temp. (Deg. C)	538	532	—	538	543	538	
Air Input to Burner (SCMH)	78.4	78.4	—	89.6	92.6	92.6	
Gas Input to Burner (SCMH)	10.36	9.52	—	9.80	11.20	11.20	Methane
Water to Burner (l/min.)	0.378	0.410	—	0.397	0.397	0.397	Methane
Compressed Air to Burner (SCMH)	12.04	12.04	—	12.04	12.04	12.04	
Compressed Air Press (kN/M^2)	138	138	—	138	138	138	
Sludge feed (l/sec.)	N/A	N/A	N/A	N/A	N/A	N/A	
Kepone Solution (l/hr.)	N/A	N/A	N/A	9	9	9	
Kepone Solution Conc. (mg/l)	N/A	N/A	N/A	0.1	0.1	0.1	
Ash (kg)	N/A	N/A	N/A	N/A	N/A	N/A	
Draft in Kiln (cm W. C.)	—	—	—	—	—	—	

TABLE E-I (continued)

Time Variable	1535	1630	1700	1730	1830	1930	COMMENTS
SCRUBBER							
Brine to Fog Nozzle (l/sec.)	0.441	0.416	0.416	0.441	0.441	0.441	
Brine to 2" Nozzle (l/sec.)	3.02	3.02	3.09	3.09	3.09	3.09	
Brine to 1" Nozzle (l/sec.)	0.945	0.945	0.945	0.976	0.976	0.976	
Brine to Cone (l/sec.)	2.52	2.71	2.71	2.71	2.71	2.71	
Brine to Scrubber (l/sec.)	1.44	1.47	1.47	1.51	1.51	1.51	
Caustic Tank level (cm)	310	302	300	297	292	286	
Brine Tank level (cm)	—	—	—	—	—	—	
Quench level (cm)	—	—	—	—	—	—	
Caustic Flow (l/min)	—	0.57	0.38	0.38	0.38	0.47	
Press @ Brine Pump (kN/M^2)	255	262	262	255	255	262	
Press @ Retention Tank (kN/M^2)	62.1	62.1	55.2	62.1	62.1	62.1	
Press @ Caustic Pump (kN/M^2)	62.1	62.1	62.1	62.1	62.1	62.1	
Scrubber pH	9.2	9.2	9.1	9.1	9.1	9.0	

FEED STARTED @ 1730

FEED STOPPED @ 1930

TABLE E-2

KIT RUN NO. 2

DATE: 1-15-77

Time Variable	1300	1330	1430	1530	1630	COMMENTS
FUME INCINERATOR						
Incinerator Temp. (Deg. C)	1093	1093	1093	1093	1093	
Total Air Input (SCMH)	560	568	568	568	560	
Gas Input @ Pilot No. 1 (SCMH)	8.96	8.82	8.82	8.54	8.82	Methane
Gas Input @ Pilot No. 2 (SCMH)	8.96	8.82	8.82	8.54	8.82	Methane
Aux. Gas Input (SCMH)	28.00	26.88	26.32	21.56	20.30	Methane
Inlet Gas Temp. (Deg. C)	448	446	444	388	381	
Stack Flow Rate (SCMH)	—	—	—	—	—	
Air in Stack Burner (SCMH)	—	—	—	—	—	
Pilot Gas to Stack Burner (SCMH)	—	—	—	—	—	
Aux. Gas to Stack Burner (SCMH)	—	—	—	—	—	
Stack Temp. (Deg. C)	—	—	—	—	—	
% Oxygen in Stack	—	—	—	4.8	—	
KILN						
Burner Gas Temp. (Deg. C)	1056	1051	1036	944	1031	
Gas Discharge Temp. (Deg. C)	538	538	538	538	538	
Air Input to Burner (SCMH)	106.4	98.0	103.6	103.6	103.6	
Gas Input to Burner (SCMH)	10.36	9.52	9.52	9.52	9.10	Methane
Water to Burner (l/min.)	0.378	0.347	0.347	0.359	0.359	
Compressed Air to Burner (SCMH)	12.18	12.04	12.04	12.04	12.04	
Compressed Air Press (kN/M^2)	138	138	138	138	138	
Sludge feed (l/sec.)	N/A	N/A	N/A	N/A	N/A	
Kepone Solution (l/hr.)	N/A	N/A	9	9	9	
Kepone Solution Conc. (mg/l)	N/A	N/A	0.1	0.1	0.1	
Ash (kg)	N/A	N/A	N/A	N/A	N/A	
Draft in Kiln (cm W.C)	—	—	—	—	—	

TABLE E-2 (continued)

Time Variable	1300	1330	1430	1530	1630	COMMENTS
SCRUBBER						
Brine to Fog Nozzle (l/sec.)	0.44	0.18	0	0	0	
Brine to 2" Nozzle (l/sec.)	3.09	3.09	3.09	3.09	3.09	
Brine to 1" Nozzle (l/sec.)	0.977	0.977	0.977	0.977	0.977	
Brine to Cone (l/sec.)	1.26	2.08	2.08	2.08	1.64	
Brine to Scrubber (l/sec.)	1.32	1.23	1.32	1.27	1.30	
Caustic Tank level (cm)	361	359	356	349	344	
Brine Tank level (cm)	–	–	–	–	–	
Quench level (cm)	–	–	–	–	–	
Caustic Flow (l/min.)	–	0.189	0.284	0.473	0.378	
Press @ Brine Pump (kN/M^2)	241	276	276	276	276	
Press @ Retention Tank (kN/M^2)	69.0	138.0	117.0	82.7	82.7	
Press @ Caustic Pump (kN/M^2)	55.2	55.2	55.2	55.2	55.2	
Scrubber pH	–	–	–	–	–	

FEED STARTED @ 1430

FEED STOPPED @ 1640

TABLE E-3 KIT RUN NO. 3 DATE: 1-22-77

Time Variable	1505	1535	1605	1635	1735	COMMENTS
FUME INCINERATOR						
Incinerator Temp. (Deg. C)	1093	1093	1093	1093	1093	
Total Air Input (SCMH)	560	552	552	552	552	
Gas Input @ Pilot No. 1 (SCMH)	2.94	2.94	2.94	2.94	2.94	Propane
Gas Input @ Pilot No. 2 (SCMH)	3.50	3.50	3.50	3.50	3.50	Propane
Aux. Gas Input (SCMH)	12.88	11.76	11.48	12.88	9.52	Propane
Inlet Gas Temp. (Deg. C)	443	451	451	452	401	
Stack Flow Rate (SCMH)	—	—	—	—	—	
Air in Stack Burner (SCMH)	—	—	—	—	—	
Pilot Gas to Stack Burner (SCMH)	—	—	—	—	—	
Aux. Gas to Stack Burner (SCMH)	—	—	—	—	—	
Stack Temp. (Deg. C)	—	—	—	—	—	
% Oxygen in Stack	—	—	—	—	—	
KILN						
Burner Gas Temp (Deg. C)	1088	1053	1082	1102	1036	
Gas Discharge Temp (Deg. C)	538	538	538	538	532	
Air Input to Burner (SCMH)	114.8	95.2	98.0	95.2	89.6	
Gas Input to Burner (SCMH)	4,90	4.34	4.56	4.68	4.48	Propane
Water to Burner (l/min.)	0.42	0.39	0.39	0.38	0.42	
Compressed Air to Burner (SCMH)	11.62	11.76	11.90	11.90	11.62	
Compressed Air Press (kN/M^2)	124	124	124	124	124	
Sludge feed (l/sec.)	N/A	N/A	N/A	N/A	N/A	
Kepone Solution (l/hr.)	N/A	N/A	N/A	9	N/A	
Kepone Solution Conc. (mg/l)	N/A	N/A	N/A	0.1	N/A	
Ash (kg)	N/A	N/A	N/A	N/A	N/A	
Draft in Kiln (cm W.C.)	—	—	—	—	—	

TABLE E-3 (continued)

Time Variable	1501	1535	1605	1635	1735	COMMENTS
SCRUBBER						
Brine to Fog Nozlle (l/sec.)	—	—	—	—	—	
Brine to 2" Nozzle (l/sec.)	3.09	3.09	3.09	3.09	3.09	
Brine to 1" Nozzle (l/sec.)	0.98	0.98	0.98	0.98	0.98	
Brine to Cone (l/sec.)	2.58	2.71	2.71	2.71	2.71	
Brine to Scrubber (l/sec.)	1.04	0.98	0.98	1.02	1.02	
Caustic Tank level (cm)	325	323	323	319	312	
Brine Tank level (cm)	—	—	—	—	—	
Quench Level (cm)	—	—	—	—	—	
Caustic Flow (l/min.)	—	0.378	0	0.567	0.473	
Press @ Brine Pump (kN/M^2)	275.8	289.6	289.6	289.6	289.6	
Press @ Retention Tank (kN/M^2)	27.58	27.58	27.58	27.58	27.58	
Press @ Caustic Pump (kN/M^2)	62.06	62.06	0	62.06	62.06	
Scrubber pH	—	9.0	9.0	8.9	9.0	

FEED STARTED @ 1638

FEED STOPPED @ 1815

TABLE E-4

KIT RUN NO. 4

DATE: 1-25-77

Time Variable	1125	1155	1230	1330	1430	COMMENTS
FUME INCINERATOR						
Incinerator Temp. (Deg. C)	1093	1093	1093	1093	1093	
Total Air Input (SCMH)	546	546	546	546	546	
Gas Input @ Pilot No. 1 (SCMH)	3.14	3.14	3.14	3.22	3.22	Propane
Gas Input @ Pilot No. 2 (SCMH)	3.36	3.36	3.36	3.44	3.50	Propane
Aux. Gas Input (SCMH)	11.2	11.2	10.9	8.4	7.84	Propane
Inlet Gas Temp. (Deg. C.)	438	447	448	393	414	
Stack Flow Rate (SCMH)	—	—	—	—	—	
Air in Stack Burner (SCMH)	—	—	—	—	—	
Pilot Gas to Stack Burner (SCMH)	—	—	—	—	—	
Aux. Gas to Stack Burner (SCMH)	—	—	—	—	—	
Stack Temp. (Deg. C)	—	—	—	—	—	
%Oxygen in Stack	—	—	—	—	—	
KILN						
Burner Gas Temp. (Deg. C)	1080	1021	997	1011	977	
Gas Discharge Temp (Deg. C)	538	538	538	538	538	
Air Input to Burner (SCMH)	151.2	109.2	112.0	109.2	106.4	
Gas Input to Burner (SCMH)	6.16	5.04	5.04	5.04	4.90	Propane
Water to Burner (l/min.)	0.504	0.397	0.410	0.441	0.473	
Compressed Air to Burner (SCMH)	11.48	12.04	11.76	11.54	11.48	
Compressed Air Press (kN/M^2)	137.9	137.9	124.1	124.1	124.1	
Sludge feed (l/sec.)	N/A	N/A	N/A	N/A	N/A	
Kepone Solution (l/hr.)	N/A	N/A	N/A	9	9	
Kepone Solution Conc. (mg/l)	N/A	N/A	N/A	10	10	
Ash (kg)	N/A	N/A	N/A	N/A	N/A	
Draft in Kiln (cm W.C.)	-0.76	-1.02	-1.27	-0.76	-0.76	

TABLE E-4 (continued)

Time Variable	1125	1155	1230	1330	1430	COMMENTS
SCRUBBER						
Brine to Fog Nozzle (l/sec.)	—	—	—	—	—	
Brine to 2" Nozzle (l/sec.)	3.09	3.09	3.09	3.09	3.09	
Brine to 1" Nozzle (l/sec.)	0.977	0.977	0.977	0.945	0.977	
Brine to Cone (l/sec.)	2.71	2.71	2.71	2.71	2.71	
Brine to Scrubber (l/sec.)	0.851	0.851	0.851	0.851	0.851	
Caustic Tank level (cm)	304.8	304.8	304.8	302.3	294.6	
Brine Tank level (cm)	—	—	—	—	—	
Quench level (cm)	—	—	—	—	—	
Caustic Flow (l/min.)	—	0	0	0.189	0.567	
Press @ Brine Pump (kN/M^2)	296.5	296.5	296.5	296.5	296.5	
Press @ Retention Tank (kN/M^2)	13.79	13.79	13.79	13.79	13.79	
Press @ Caustic Pump (kN/M^2)	0	0	0	55.16	55.16	
Scrubber pH	—	—	—	—	—	

FEED STARTED @ 1240

FEED STOPPED @ 1430

TABLE E-5 KIT RUN NO. 5 DATE: 1-26-77

Time Variable	1330	1420	COMMENTS
FUME INCINERATOR			
Incinerator Temp (Deg. C)	1093	1093	
Total Air Input (SCMH)	582.4	560.0	
Gas Input @ Pilot No. 1 (SCMH)	3.14	3.16	Propane
Gas Input @ Pilot No. 2 (SCMH)	3.44	3.42	Propane
Aux. Gas Input (SCMH)	9.52	9.52	Propane
Inlet Gas Temp. (Deg. C)	437	437	
Stack Flow Rate (SCMH)	—	—	
Air in Stack Burner (SCMH)	—	—	
Pilot Gas to Stack Burner (SCMH)	—	—	
Aux. Gas to Stack Burner (SCMH)	—	—	
Stack Temp. (Deg. C)	—	—	
% Oxygen in Stack	—	4.7	
KILN			
Burner Gas Temp. (Deg. C)	999	—	
Gas Discharge Temp. (Deg. C)	538	—	
Air Input to Burner (SCMH)	109.2	—	
Gas Input to Burner (SCMH)	4.98	—	Propane
Water to Burner (l/min.)	0.36	—	
Compressed Air to Burner (SCMH)	12.04	—	
Compressed Air Press (kN/M^2)	124.1	—	
Sludge feed (l/sec.)	—	—	
Kepone Solution (l/hr.)	—	—	
Kepone Solution Conc. (mg/l)	—	—	
Ash (kg)	—	—	
Draft in Kiln (cm W.C.)	-1.02	—	

TABLE E-5 (continued)

Time Variable	1330	1420	COMMENTS
SCRUBBER			
Brine to Fog Nozzle (l/sec.)	—	—	
Brine to 2" Nozzle (l/sec.)	3.09	—	
Brine to 1" Nozzle (l/sec.)	0.98	—	
Brine to Cone (l/sec.)	2.33	—	
Brine to Scrubber (l/sec.)	0.72	—	
Caustic Tank level (cm)	293	—	
Brine Tank level (cm)	—	—	
Quench level (cm)	—	—	
Caustic Flow (l/min.)	0	—	
Press @ Brine Pump (kN/M^2)	296.5	—	
Press @ Retention Tank (kN/M^2)	13.79	—	
Press @ Caustic Pump (kN/M^2)	0	—	
Scrubber pH	—	—	

FEED STARTED @ — RUN ABORTED

FEED STOPPED @ —

TABLE E-6

KIT RUN NO. 6

DATE: 2-14-77

Time Variable	1215	1245	1315	1415	1515	COMMENTS
FUME INCINERATOR						
Incinerator Temp. (Deg. C)	1093	1093	1093	1093	1093	
Total Air Input (SCMH)	546.0	537.6	534.8	537.6	537.6	
Gas Input @ Pilot No. 1 (SCMH)	2.9	3.0	2.9	2.9	2.9	Propane
Gas Input @ Pilot No. 2 (SCMH)	3.2	3.2	3.1	3.1	3.1	Propane
Aux. Gas Input (SCMH)	12.7	11.9	12.5	11.6	11.9	Propane
Inlet Gas Temp (Deg. C.)	442	—	—	421	448	
Stack Flow Rate (SCMH)	—	—	—	—	—	
Air in Stack Burner (SCMH)	198.8	198.8	196.0	194.9	196.0	
Pilot Gas to Stack Burner (SCMH)	—	—	—	0.17	—	
Aux. Gas to Stack Burner (SCMH)	—	—	—	0.59	—	
Stack Temp. (Deg. C)	77	77	74	116	121	
%Oxygen in Stack	6.5	7.0	5.5	—	—	
KILN						
Burner Gas Temp. (Deg. C)	993	952	1010	939	893	
Gas Discharge Temp. (Deg. C)	491	482	410	477	516	
Air Input to Burner (SCMH)	112.0	103.6	201.6	168.0	166.6	
Gas Input to Burner (SCMH)	6.16	5.94	9.66	8.54	8.26	Propane
Water to Burner (l/min.)	0.37	0.37	0.55	0.54	0.57	
Compressed Air to Burner (SCMH)	12.0	12.3	12.3	11.5	11.5	
Compressed Air Press (kN/M^2)	138	138	138	138	138	
Sludge feed (l/sec.)	N/A	N/A	0.01	0.01	—	Feed Line plugged total sludge fed = 0.049 M^3
Kepone Solution (l/hr.)	N/A	N/A	N/A	N/A	N/A	
Kepone Solution Conc.(%)	N/A	N/A	0	0	0	
Ash (kg)	—	—	—	—	—	
Draft in Kiln (cm W.C.)	—	—	—	—	—	

TABLE E-6 (continued)

Time Variable	1215	1245	1315	1415	1515	COMMENTS
SCRUBBER						
Brine to Fog Nozzle (l/sec.)	—	—	—	—	—	
Brine to 2" Nozzle (l/sec.)	3.0	3.0	3.0	3.0	3.0	
Brine to 1" Nozzle (l/sec.)	0.98	0.98	0.98	0.98	0.98	
Brine to Cone (l/sec.)	2.7	2.7	2.7	2.7	2.7	
Brine to Scrubber (l/sec.)	1.13	1.13	1.12	1.10	1.10	
Caustic Tank level (cm)	324	322	320	316	311	
Brine Tank level (cm)	—	—	—	—	—	
Quench level (cm)	—	—	—	—	—	
Caustic Flow (l/min.)	—	0.38	0.28	0.28	0.38	
Press @ Brine Pump (kN/M^2)	290	293	293	293	293	
Press @ Retention Tank (kN/M^2)	82.7	82.7	96.5	96.5	96.5	
Press @ Caustic Pump (kN/M^2)	62.1	55.2	55.2	55.2	55.2	
Scrubber pH	9.3	9.4	9.2	9.3	9.3	

FEED STARTED @ 1308

FEED STOPPED @ 1520

TABLE E-7 KIT RUN NO. 8 DATE: 2-18-77

Time Variable	1535	1630	1700	1730	1830	1930	2030	2115	COMMENTS
FUME INCINERATOR									
Incinerator Temp. (Deg. C)	1149	1149	1149	1149	1149	1149	1149	1149	
Total Air Input (SCMH)	512.4	518.0	518.0	518.0	518.0	518.0	518.0	518.0	
Gas Input @ Pilot No. 1 (SCMH)	2.82	2.86	2.86	2.86	2.91	2.91	2.94	2.94	Propane
Gas Input @ Pilot No. 2 (SCMH)	3.08	3.05	3.05	3.05	3.08	3.08	3.11	3.19	Propane
Aux. Gas Input (SCMH)	12.0	11.5	11.2	11.2	10.9	11.2	10.9	10.6	Propane
Inlet Gas Temp. (Deg. C)	—	363	349	341	329	299	296	308	
Stack Flow Rate (SCMH)	—	—	—	—	—	—	—	—	
Air in Stack Burner (SCMH)	195	195	195	195	195	195	195	195	
Pilot Gas to Stack Burner (SCMH)	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	Propane
Aux. Gas to Stack Burner (SCMH)	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	Propane
Stack Temp. (Deg. C)	—	132	132	138	135	132	132	132	
% Oxygen in Stack	4.4	4.7	5.0	5.0	5.0	5.0	4.7	4.6	
KILN									
Burner Gas Temp. (Deg. C)	849	821	824	832	829	838	843	837	
Gas Discharge Temp. (Deg. C)	364	388	371	366	349	310	316	329	
Air Input to Burner (SCMH)	169.4	168.0	168.0	168.6	169.4	189.0	187.6	189.0	
Gas Input to Burner (SCMH)	8.40	8.26	8.26	8.54	8.57	9.24	9.32	9.24	Propane
Water to Burner (l/min.)	—	—	—	—	—	—	—	—	
Compressed Air to Burner (SCMH)	14.3	14.4	14.3	14.3	14.4	14.3	14.4	14.4	
Compressed Air Press (kN/M^2)	124	124	124	124	124	124	124	124	
Sludge Feed (l/sec.)	N/A	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
Kepone Solution (l/hr.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Kepone Solution Conc. (%)	N/A	1.2	1.2	1.2	1.2	1.2	1.2	1.2	
Ash (kg)	—	—	—	—	—	—	—	—	
Draft in Kiln (cm W.C.)	-0.5	-0.5	-0.5	-0.5	-0.5	-0.8	-0.5	-0.8	

TABLE E-7 (continued)

Time Variable	1535	1630	1700	1730	1830	1930	2030	2115	COMMENTS
SCRUBBER									
Brine to Fog Nozzle (l/sec.)	—	—	—	—	—	—	—	—	
Brine to 2" Nozzle (l/sec.)	3.0	3.1	3.1	3.1	3.0	3.1	3.0	3.0	
Brine to 1" Nozzle (l/sec.)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	
Brine to Cone (l/sec.)	1.4	1.4	1.4	1.4	1.4	1.4	1.3	1.3	
Brine to Scrubber (l/sec.)	0.85	1.0	1.0	1.0	0.95	1.0	—	1.1	
Caustic Tank level (cm)	301	300	296	293	287	286	282	278	
Brine Tank level (cm)	—	—	—	—	—	—	—	—	
Quench level (cm)	—	—	—	—	—	—	—	—	
Caustic Flow (l/min.)	—	0.66	0.57	0.57	0.57	—	0.57	0.47	
Press @ Brine Pump (kN/M^2)	303	290	290	290	290	290	303	303	
Press @ Retention Tank (kN/M^2)	117	117	117	124	90	97	103	82	
Press @ Caustic Pump (kN/M^2)	—	55.2	55.2	55.2	69.0	—	62.1	62.1	
Scrubber pH	—	9.3	9.3	9.4	9.4	9.3	9.3	9.5	

FEED STARTED @ 1615

FEED STOPPED @ 2115

TABLE E-8 KIT RUN NO. 9 DATE: 2-23-77

Time Variable	1245	1330	1400	1430	1500	1530	1600	1630	1700	COMMENTS
FUME INCINERATOR										
Incinerator Temp. (Deg. C)	1093	1093	1093	1093	1093	1093	1093	1093	1093	
Total Air Input (SCMH)	546.0	546.0	540.0	540.4	540.4	540.4	546.0	546.0	546.0	
Gas Input @ Pilot No. 1 (SCMH)	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	Propane
Gas Input @ Pilot No. 2 (SCMH)	3.0	3.0	2.9	2.9	2.9	2.9	2.9	2.9	2.9	Propane
Aux. Gas Input (SCMH)	11.2	11.2	11.2	11.2	11.2	11.5	11.2	11.2	9.2	Propane
Inlet Gas Temp. (Deg. C)	326	334	321	260	272	262	254	246	246	
Stack Flow Rate (SCMH)	—	—	—	—	—	—	—	—	—	
Air in Stack Burner (SCMH)	194.6	194.6	194.6	194.6	194.6	194.6	194.6	194.6	194.6	
Pilot Gas to Stack Burner (SCMH)	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	Propane
Aux. Gas to Stack Burner (SCMH)	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	Propane
Stack Temp. (Deg. C)	143	143	141	141	138	143	138	138	143	
% Oxygen in Stack	5.5	5.5	6.0	6.0	6.3	6.3	6.1	5.0	6.8	
KILN										
Burner Gas Temp (Deg. C)	755.6	755.6	690.0	687.8	688.9	682.8	678.9	678.3	677.2	
Gas Discharge Temp. (Deg. C)	343.3	332.2	282.2	280.0	254.4	243.3	226.7	226.7	190.6	
Air Input to Burner (SCMH)	187.6	187.6	190.4	190.4	191.2	190.4	190.4	190.4	190.4	
Gas Input to Burner (SCMH)	7.3	7.1	7.3	7.1	7.3	7.1	7.1	7.1	7.1	Propane
Water to Burner (l/min.)	—	—	—	—	—	—	—	—	—	
Compressed Air to Burner (SCMH)	—	—	—	—	—	—	—	—	—	
Compressed Air Press (kN/M^2)	—	—	—	—	—	—	—	—	—	
Sludge Feed (l/sec.)	N/A	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
Kepone Solution (l/hr.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Kepone Solution Conc. (%)	N/A	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	
Ash (kg)	—	—	—	—	—	—	—	—	—	
Draft in Kiln (cm W.C.)	-0.8	-1.0	-0.8	-0.8	-1.3	-0.5	-0.5	-0.5	-0.6	

TABLE E-8 (continued)

Time Variable	1245	1330	1400	1430	1500	1530	1600	1630	1700	COMMENTS
SCRUBBER										
Brine to Fog Nozzle (l/sec.)	—	—	—	—	—	—	—	—	—	
Brine to 2" Nozzle (l/sec.)	3.09	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	
Brine to 1" Nozzle (l/sec.)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	
Brine to Cone (l/sec.)	1.3	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.5	
Brine to Scrubber (l/sec.)	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	
Caustic Tank level (cm)	137.75	137.75	137.75	137.75	137.75	137.75	137.75	137.75	137.75	
Brine Tank level (cm)	—	—	—	—	—	—	—	—	—	
Quench level (cm)	—	—	—	—	—	—	—	—	—	
Caustic Flow (l/min.)	0	0	0	0	0	0	0	0	0	
Press @ Brine Pump (kN/M^2)	310.3	317.2	317.2	317.2	317.2	317.2	317.2	317.2	317.2	
Press @ Retention Tank (kN/M^2)	96.5	75.8	69.0	89.6	82.7	75.8	69.0	69.0	69.0	
Press @ Caustic Pump (kN/M^2)	0	0	0	0	0	0	0	0	0	
Scrubber pH	9.5	9.3	9.4	9.3	9.4	9.3	9.3	9.3	9.3	

FEED STARTED @ 1318

FEED STOPPED @ 1718

TABLE E-9 KIT RUN NO. 10 DATE: 2-24-77

Time Variable	1415	1445	1515	1545	1615	1645	1715	1800	COMMENTS
FUME INCINERATOR									
Incinerator Temp. (Deg. C)	1037.8	1037.8	1037.8	1037.8	1037.8	1037.8	1037.8	1037.8	
Total Air Input (SCMH)	588.0	579.6	574.0	574.0	588.0	579.6	588.0	588.0	
Gas Input @ Pilot No. 1 (SCMH)	2.5	2.7	2.7	2.7	2.7	2.7	2.7	2.7	Propane
Gas Input @ Pilot No. 2 (SCMH)	3.1	2.9	2.9	2.9	2.9	3.0	3.0	3.0	Propane
Aux. Gas Input (SCMH)	9.5	10.9	10.6	10.3	10.3	10.3	9.5	9.5	Propane
Inlet Gas Temp. (Deg. C)	273.9	348.9	361.7	346.7	320.6	306.7	296.7	273.9	
Stack Flow Rate (SCMH)	187.6	187.6	187.6	184.8	187.6	189.0	187.6	187.6	
Air in Stack Burner (SCMH)	—	—	—	—	—	—	—	—	
Pilot Gas to Stack Burner (SCMH)	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	Propane
Aux. Gas to Stack Burner (SCMH)	1.5	1.5	1.5	1.5	1.46	1.46	1.46	1.46	Propane
Stack Temp. (Deg. C)	137.8	137.8	137.8	135.0	135.0	140.6	146.1	137.8	
% Oxygen in Stack	5.5	6.5	6.5	6.8	6.7	6.2	7.7	8.0	
KILN									
Burner Gas Temp. (Deg. C)	777.2	758.3	765.0	747.2	713.3	748.9	750.0	757.2	
Gas Discharge Temp. (Deg. C)	354.4	398.9	387.8	348.9	315.6	310.0	298.9	265.6	
Air Input to Burner (SCMH)	190.4	190.4	189.0	189.0	190.4	190.4	191.8	191.8	
Gas Input to Burner (SCMH)	7.3	7.3	7.1	7.3	7.2	7.2	7.2	7.2	Propane
Water to Burner (l/min.)	0	0	0	0	0	0	0	0	
Compressed Air to Burner (SCMH)	0	0	0	0	0	0	0	0	
Compressed Air Press (kN/M^2)	0	0	0	0	0	0	0	0	
Sludge feed (l/sec.)	N/A	N/A	0.01	0.01	0.01	0.01	0.01	0.01	
Kepone Solution (l/hr.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Kepone Solution Conc. (%)	N/A	N/A	0.6	0.6	0.6	0.6	0.6	0.6	
Ash (kg)	—	—	—	—	—	—	—	—	
Draft in Kiln (cm W.C.)	-1.0	-1.0	-0.5	-1.3	-1.3	-0.5	-0.5	-1.0	

TABLE E-9 (continued)

Time Variable	1415	1445	1515	1545	1615	1645	1715	1800	COMMENTS
SCRUBBER									
Brine to Fog Nozzle (l/sec.)	—	—	—	—	—	—	—	—	
Brine to 2" Nozzle (l/sec.)	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	
Brine to 1" Nozzle (l/sec.)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	
Brine to Cone (l/sec.)	1.4	1.4	1.6	1.6	1.6	1.5	1.5	1.5	
Brine to Scrubber (l/sec.)	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	
Caustic Tank level (cm)	350	350	350	350	350	350	350	350	
Brine Tank level (cm)	—	—	—	—	—	—	—	—	
Quench level (cm)	—	—	—	—	—	—	—	—	
Caustic Flow (l/min.)	0	0	0	0	0	0	0	0	
Press @ Brine Pump (kN/M^2)	317.2	317.2	317.2	317.2	317.2	317.2	296.5	289.6	
Press @ Retention Tank (kN/M^2)	62.1	62.1	62.1	62.1	69.0	62.1	69.0	62.1	
Press @ Caustic Pump (kN/M^2)	0	0	0	0	0	0	0	0	
Scrubber pH	9.3	9.2	9.4	9.3	9.5	9.4	9.5	9.5	

FEED STARTED @ 1450

FEED STOPPED @ 1820

TABLE E-10 KIT RUN NO. 11 DATE: 2-25-77

Time Variable	1230	1300	1330	1400	1430	1500	1530	1550	COMMENTS
FUME INCINERATOR									
Incinerator Temp. (Deg. C)	1093.3	1093.3	1093.3	1093.3	1093.3	1093.3	1093.3	1093.3	
Total Air Input (SCMH)	551.6	551.6	551.6	551.6	546.0	551.6	551.6	551.6	
Gas Input @ Pilot No. 1 (SCMH)	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	Propane
Gas Input @ Pilot No. 2 (SCMH)	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	Propane
Aux. Gas Input (SCMH)	10.9	11.2	10.6	9.9	9.9	9.9	9.5	9.2	Propane
Inlet Gas Temp. (Deg. C)	319.4	374.4	403.3	409.4	423.3	430.6	432.8	438.4	
Stack Flow Rate (SCMH)	—	—	—	—	—	—	—	—	
Air in Stack Burner (SCMH)	189	189	189	189	189	189	189	189	
Pilot Gas to Stack Burner (SCMH)	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	Propane
Aux. Gas to Stack Burner (SCMH)	1.1	1.3	1.3	1.3	1.3	1.3	1.3	1.3	Propane
Stack Temp. (Deg. C)	132.2	135.0	132.2	132.2	132.2	137.8	137.8	137.8	
% Oxygen in Stack	5.0	6.0	6.5	3.2	3.0	3.0	3.1	3.2	
KILN									
Burner Gas Temp. (Deg. C)	765.6	768.8	763.3	761.1	761.1	761.7	761.1	757.2	
Gas Discharge Temp. (Deg. C)	393.3	454.4	460.0	457.2	479.4	482.2	482.2	482.2	
Air Input to Burner (SCMH)	190.4	189.0	189.0	190.4	190.4	189.0	189.0	189.0	
Gas Input to Burner (SCMH)	7.14	7.20	7.14	7.14	7.14	7.14	7.20	7.20	Propane
Water to Burner (l/min.)	0	0	0	0	0	0	0	0	
Compressed Air to Burner (SCMH)	0	0	0	0	0	0	0	0	
Compressed Air Press (kN/M^2)	0	0	0	0	0	0	0	0	
Sludge feed (l/sec.)	N/A	N/A	0.1	0.1	0.1	0.1	0.1	0.1	
Kepone Solution (l/hr.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Kepone Solution Conc.(%)	N/A	N/A	4.16	4.16	4.16	4.16	4.16	4.16	Dry Basis
Ash (kg)	—	—	—	—	—	—	—	—	
Draft in Kiln (cm W.C.)	-1.02	-0.25	-0.51	-0.76	-0.76	-0.51	-1.02	-0.25	

TABLE E-10 (continued)

Time Variable	1230	1300	1330	1400	1430	1500	1530	1550	COMMENTS
SCRUBBER									
Brine to Fog Nozzle (l/sec.)	—	—	—	—	—	—	—	—	
Brine to 2" Nozzle (l/sec.)	3.15	3.15	3.06	3.15	3.15	3.18	3.15	3.12	
Brine to 1" Nozzle (l/sec.)	1.01	1.01	0.98	1.01	1.01	0.99	0.99	0.99	
Brine to Cone (l/sec.)	1.51	1.51	1.39	1.51	1.51	1.51	1.51	1.76	
Brine to Scrubber (l/sec.)	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	
Caustic Tank level (cm)	350	350	350	348	344	342	342	342	
Brine Tank level (cm)	—	—	—	—	—	—	—	—	
Quench level (cm)	—	—	—	—	—	—	—	—	
Caustic Flow (l/min.)	0	0	0	19.05	19.05	19.05	0	0	
Press @ Brine Pump (kN/M^2)	310	310	310	310	310	310	317	317	
Press @ Retention Tank (kN/M^2)	69	69	69	69	96.5	96.5	69	69	
Press @ Caustic Pump (kN/M^2)	0	0	0	55.2	55.2	55.2	0	0	
Scrubber pH	9.2	9.2	9.2	9.2	9.3	9.6	9.8	9.8	

FEED STARTED @ 1328

FEED STOPPED @ 1600

TABLE E-11

KEPONE INCINERATION TESTS DATA SUMMARY

Run No.	Date	Kepone Feed gm/hr.	Incinerator* Temp. Deg.C.	Kiln* Inlet Temp. Deg. C	Kiln* Outlet Temp. Deg. C	Flow through Incinerator SCMH	Flow through Stack SCMH	Incinerator Inlet Temp. Deg. C	% O_2	Residence Time Sec.	Kiln** Inlet Temp. Deg. C	Kiln** Outlet Temp. Deg. C	Incinerator** Inlet Temp. Deg. C	Feed Time Hours
1	1/14/77	0.9	1260	1024	538	764.4	1384.6	438	3.75	2.15	1016	538	407	2.0
2	1/15/77	0.9	1093	1036	538	775.9	1315.2	444	4.8	2.38	1031	538	381	2.0
3	1/22/77	0.9	1093	1102	538	771.1	1307.0	452	—	2.39	1036	532	401	1.67
4	1/25/77	90	1093	997	538	755.3	1280.3	448	—	2.44	977	538	414	1.67
5	1/26/77	None	1093	999	538	773.6	1311.2	437	4.7	2.39	999	538	437	—
6	2/14/77	None	1093	952	482	998.2	1722.6	442	5.5	2.06	893	516	448	2.0
7	2/17/77	410	1149	877	427	—	—	427	3.7	—	877	427	427	0.33
8	2/18/77	470	1149	849	364	814.0	1607.2	363	4.4	2.18	837	329	308	5.0
9	2/23/77	250	1093	700	343	826.0	1597.0	326	5.5	2.23	677	191	246	4.0
10	2/24/77	270	1038	758	399	873.3	1639.1	349	6.5	2.20	757	266	274	3.5
11	2/25/77	1510	1093	763	454	818.2	1578.4	374	3.1	2.26	757	482	434	2.5

*At Start of Run

**At End of Run

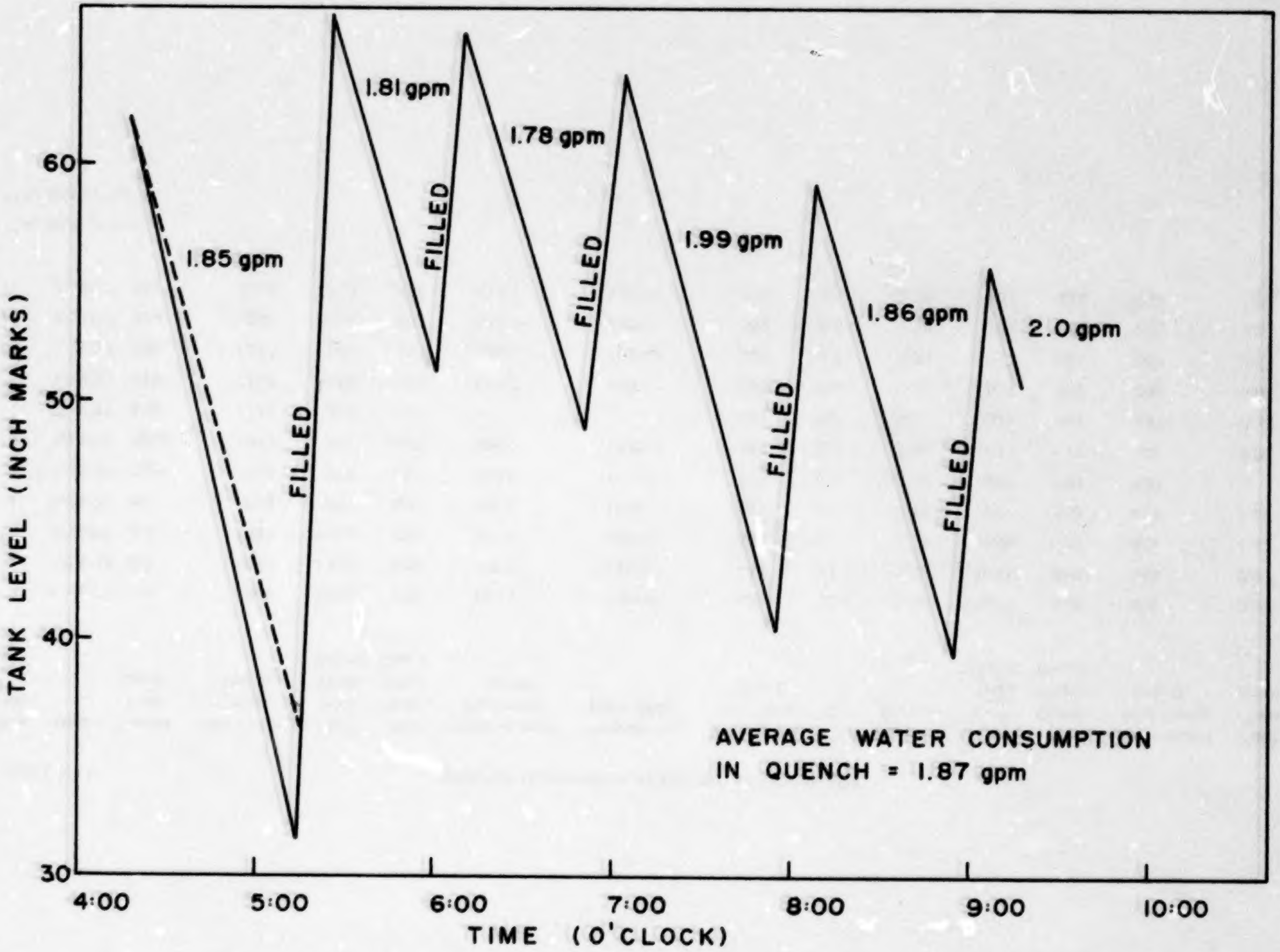


FIGURE - E12 : QUENCH WATER FOR KIT RUN NO. 8

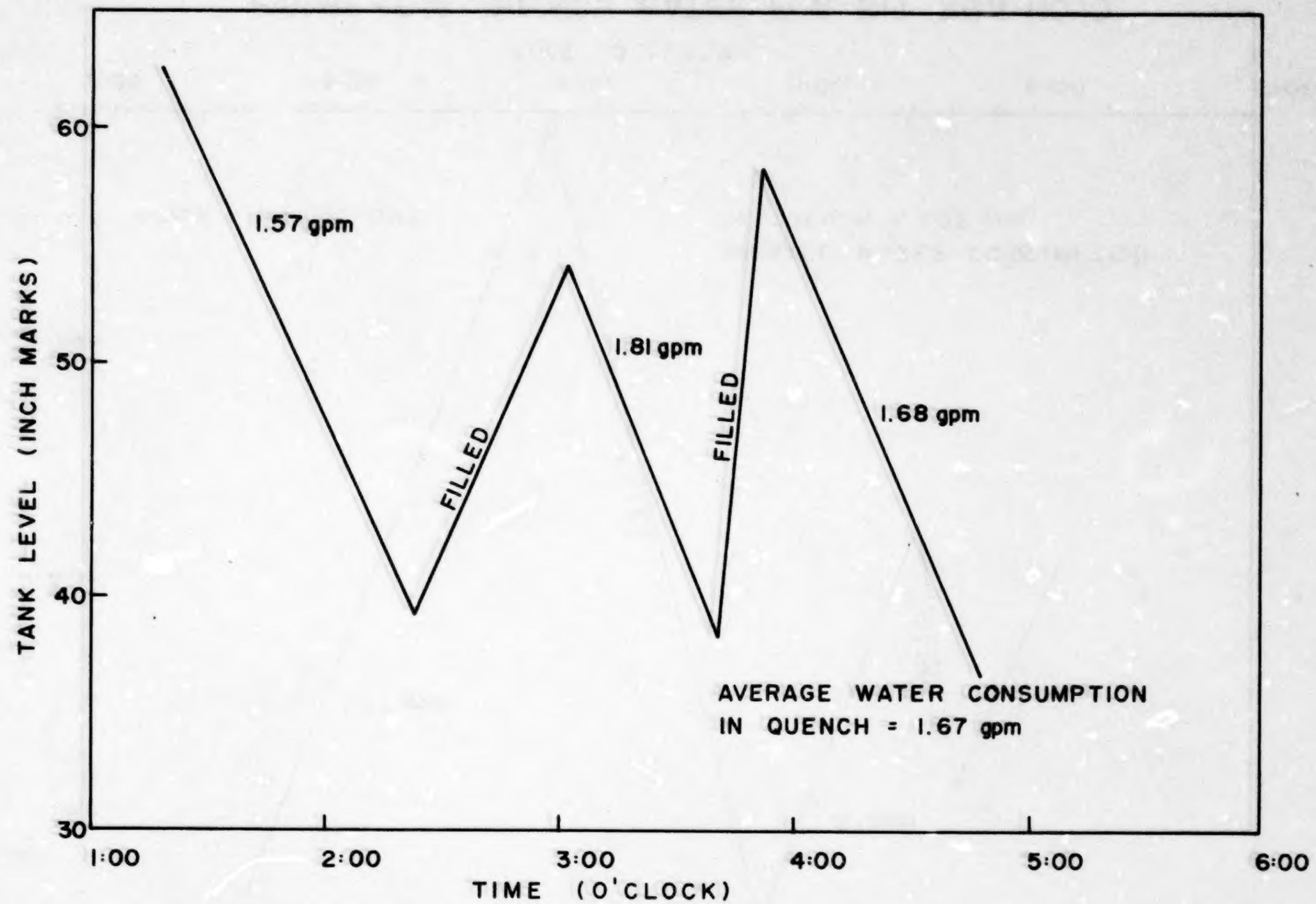


FIGURE - E13 : QUENCH WATER FOR KIT RUN NO.9

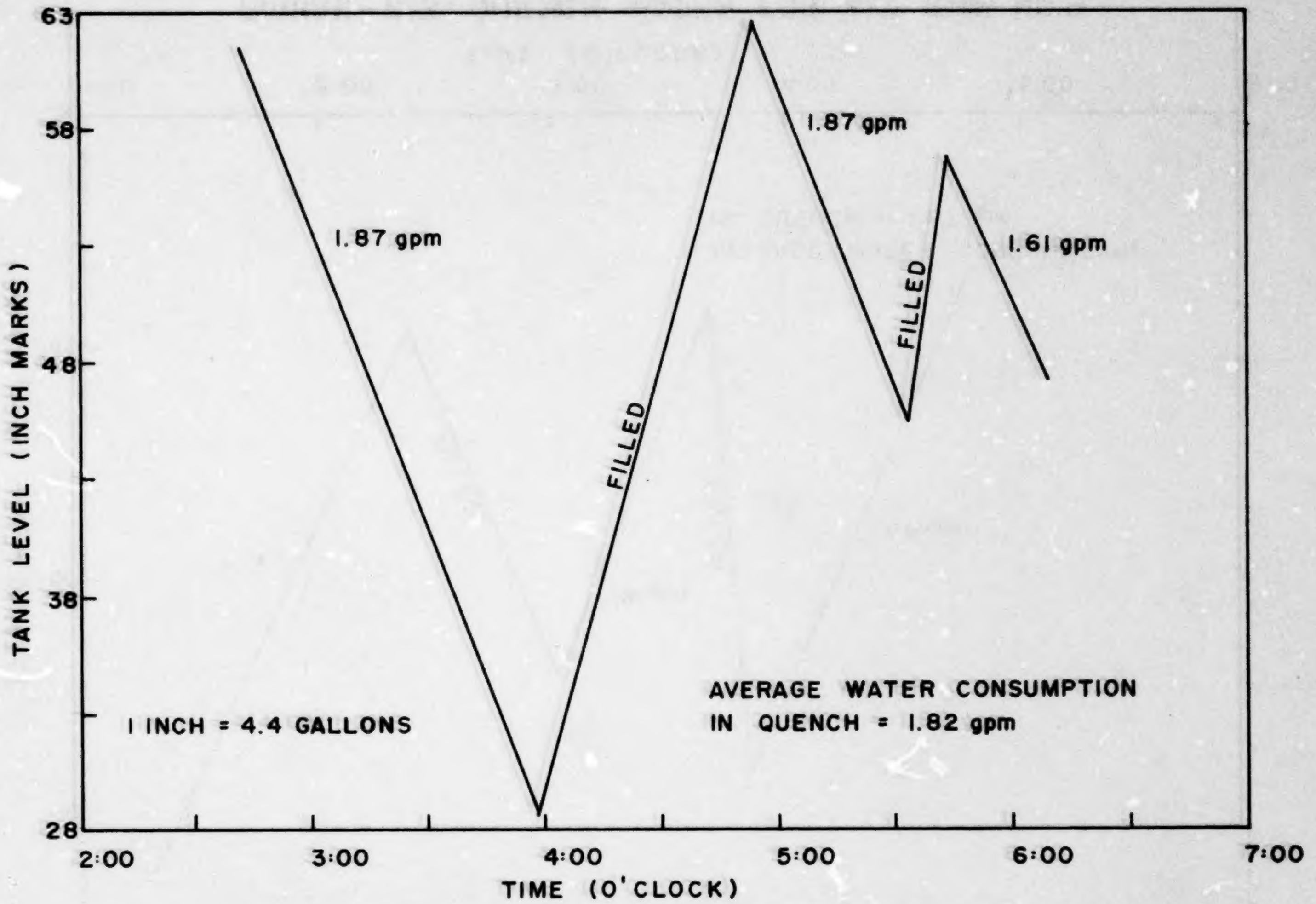


FIGURE - E14 : QUENCH WATER FOR KIT RUN NO.10

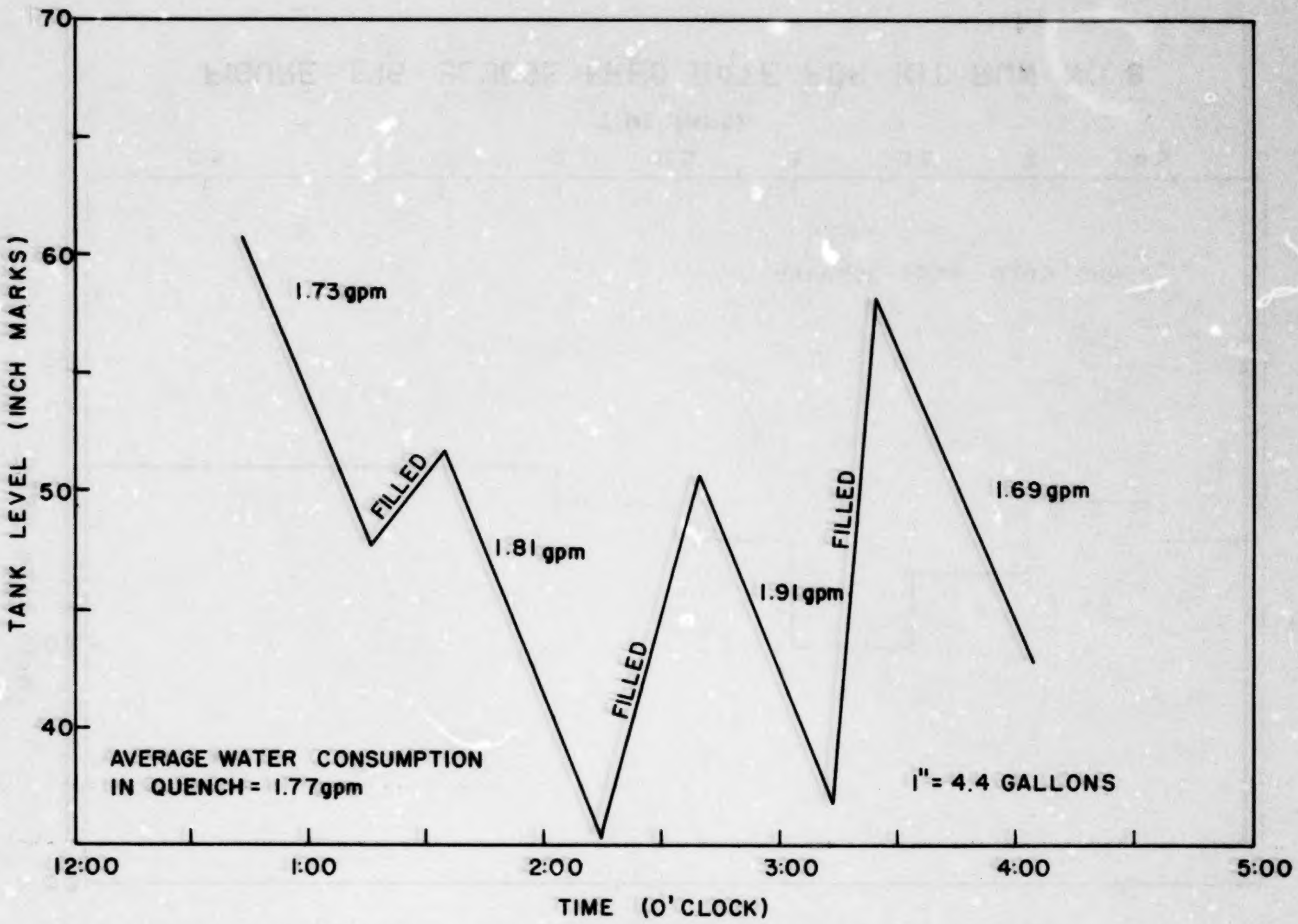


FIGURE - E15: QUENCH WATER FOR KIT RUN NO.11

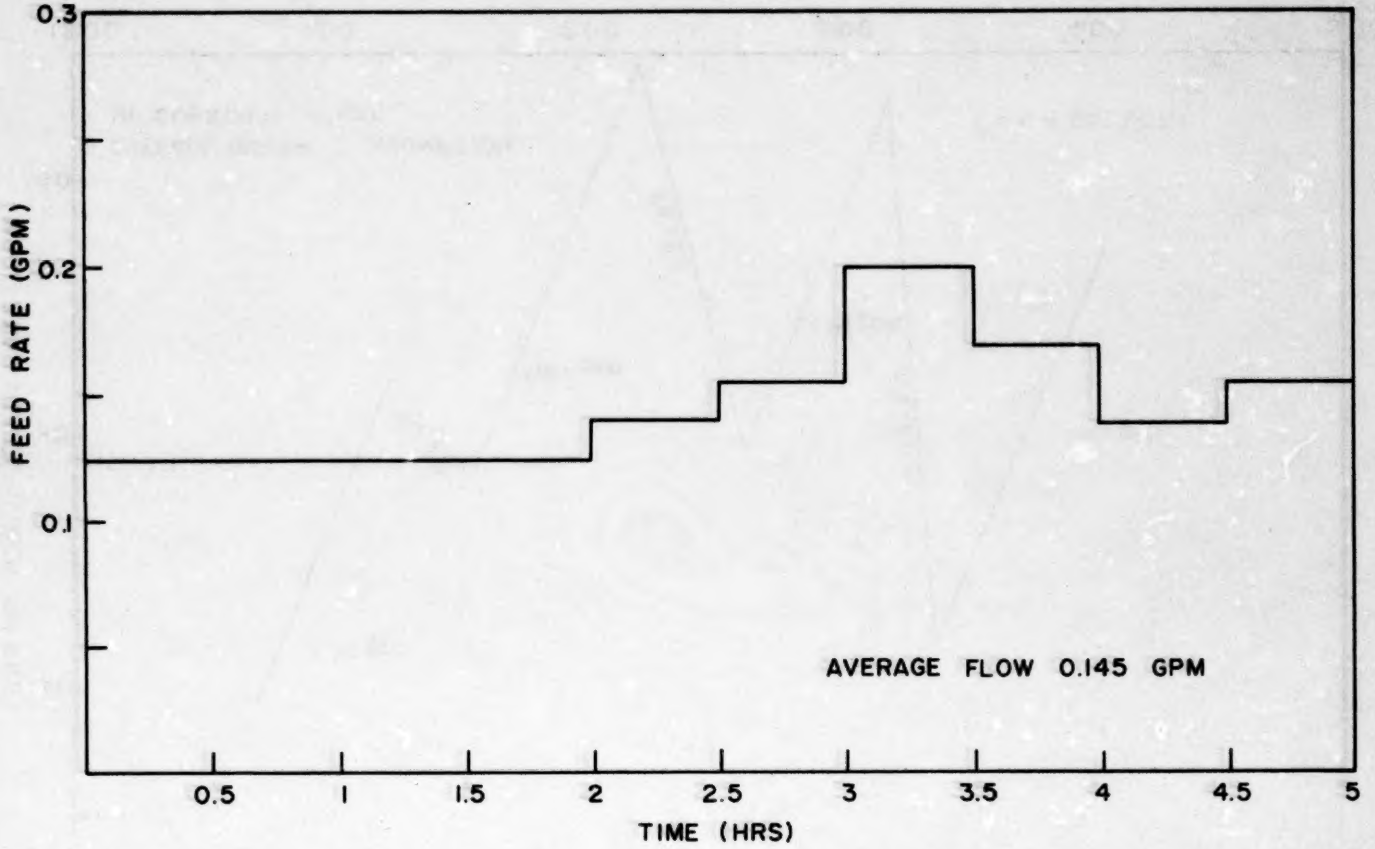


FIGURE - E16 : SLUDGE FEED RATE FOR KIT RUN NO. 8

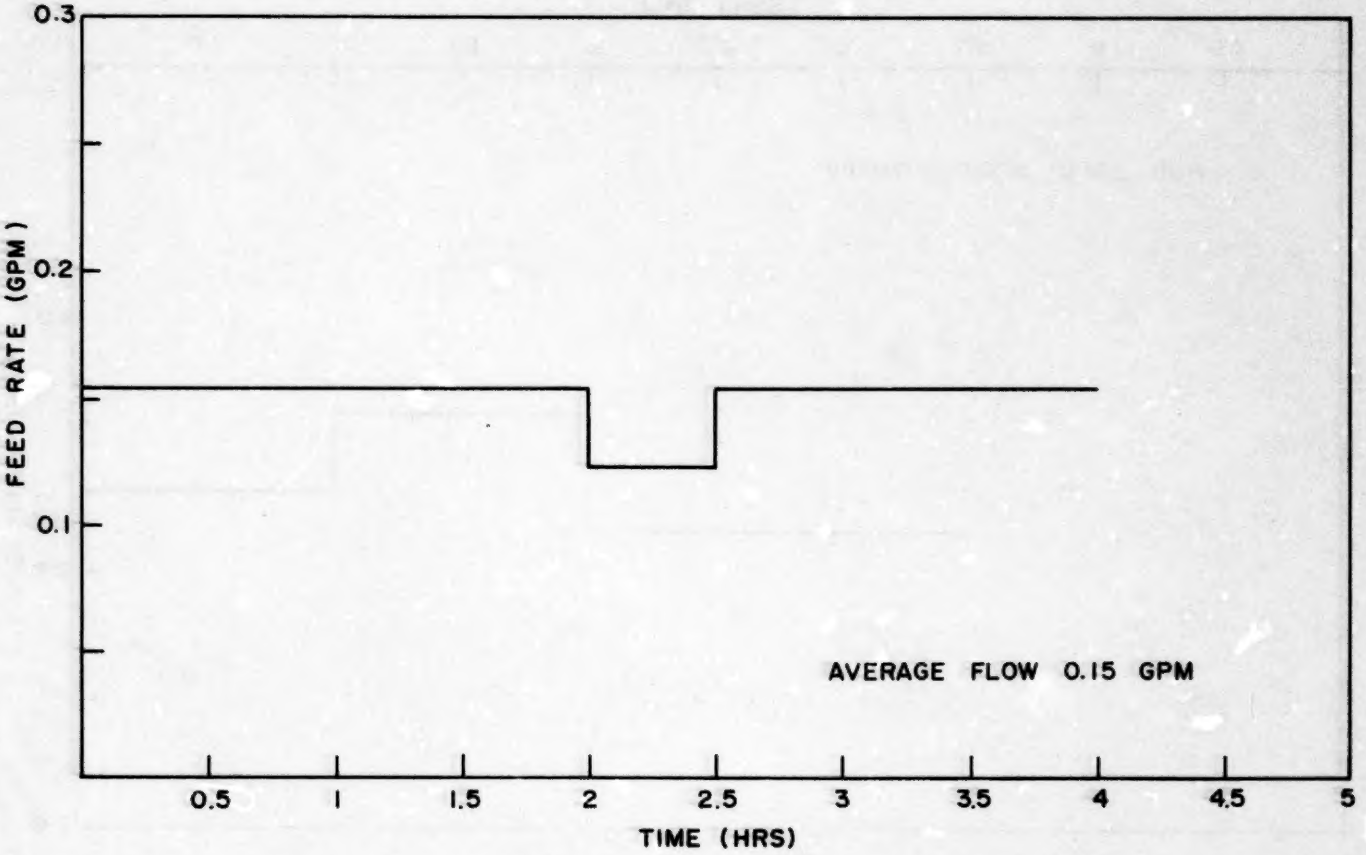


FIGURE - E17: SLUDGE FEED RATE FOR KIT RUN NO. 9

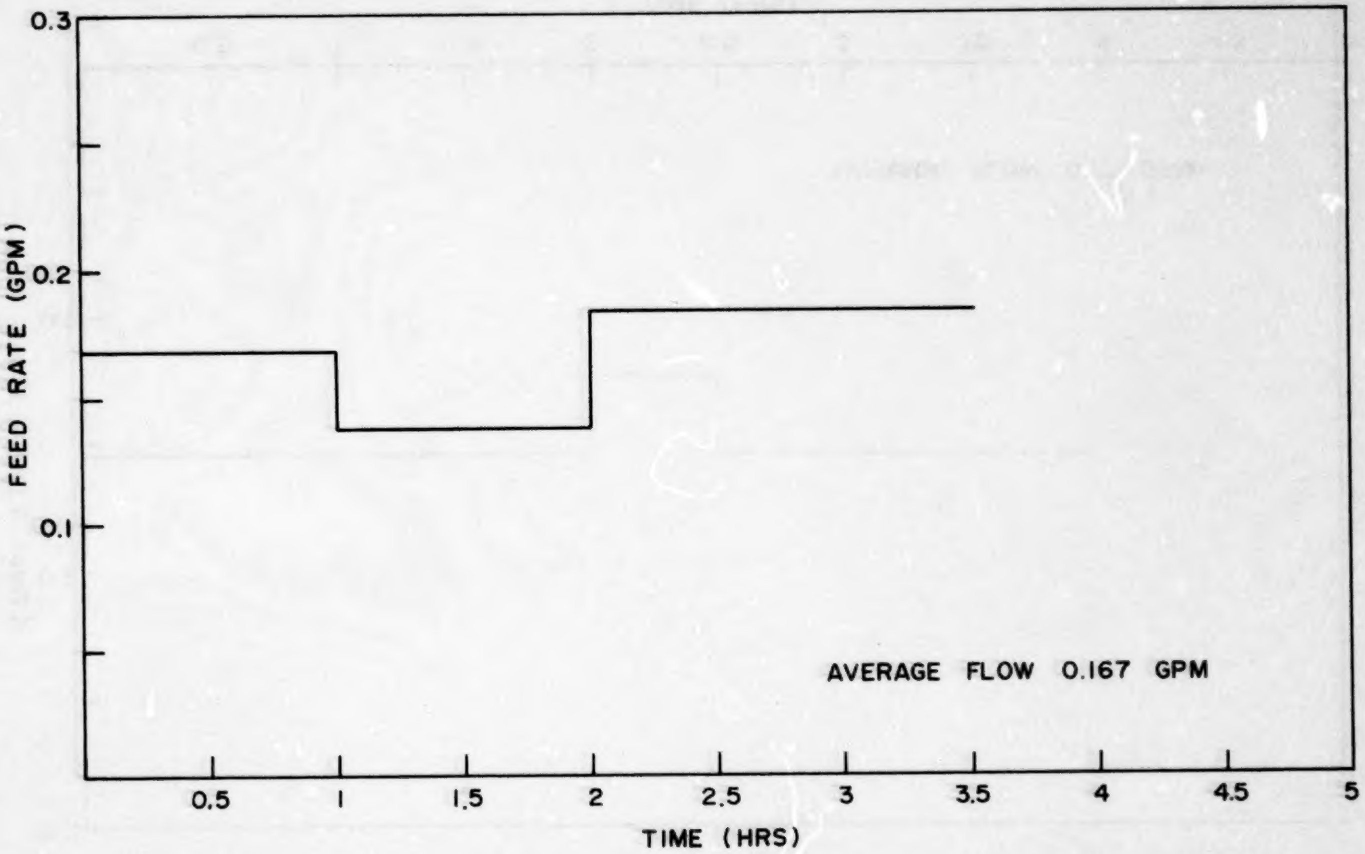


FIGURE - E18: SLUDGE FEED RATE FOR KIT RUN NO. 10

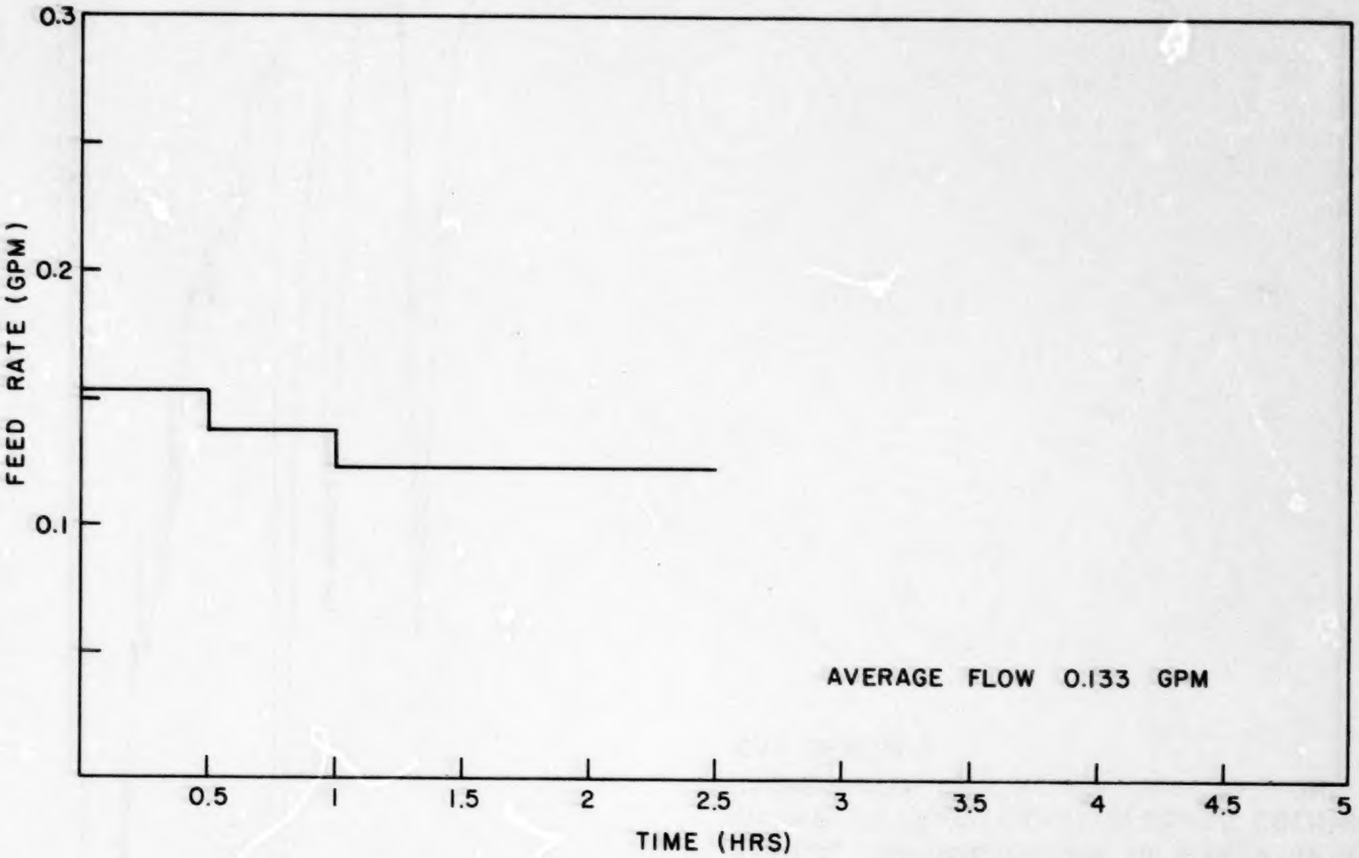


FIGURE - E19: SLUDGE FEED RATE FOR KIT RUN NO. 11

APPENDIX F. TYPICAL CHROMATOGRAMS

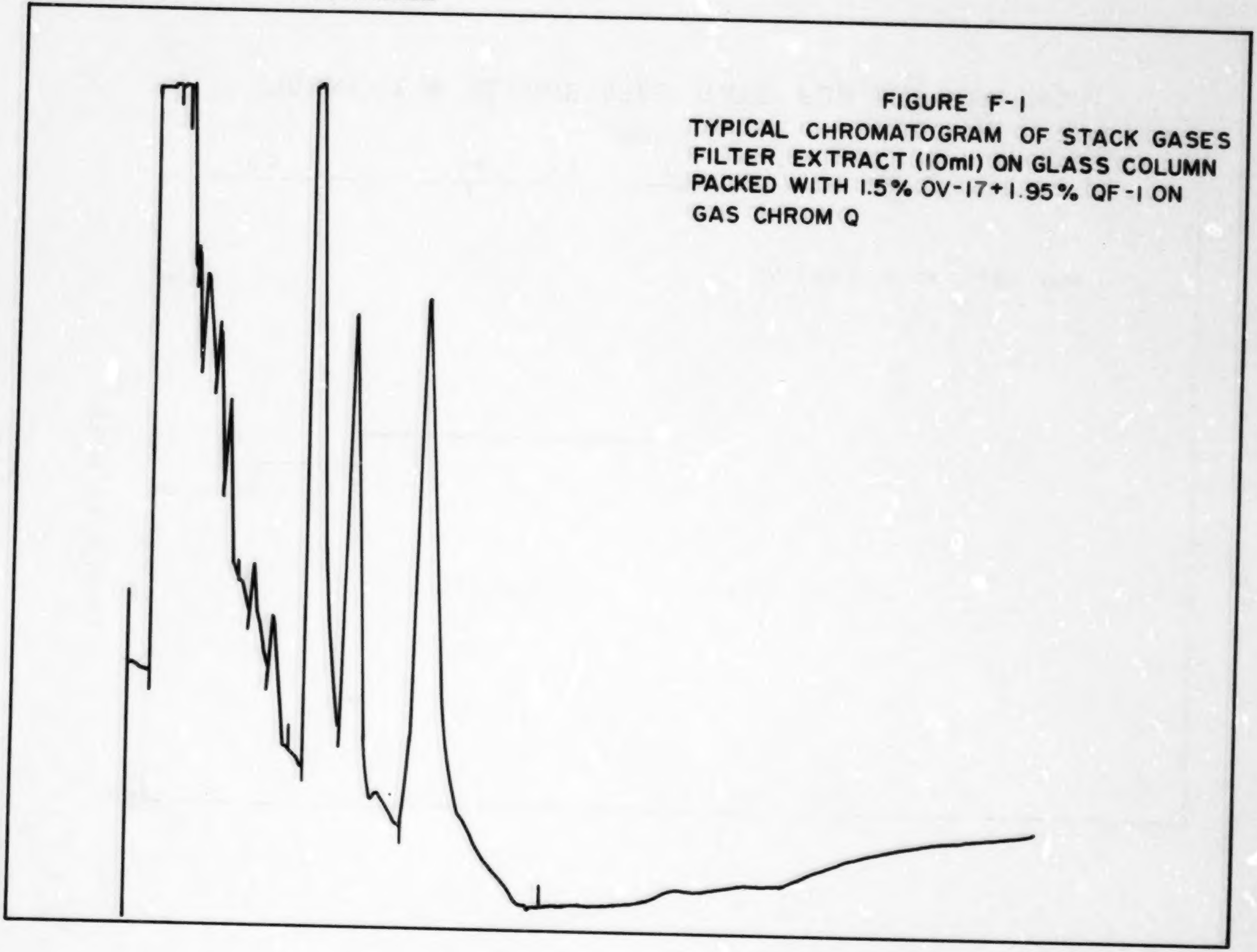


FIGURE F-1

TYPICAL CHROMATOGRAM OF STACK GASES FILTER EXTRACT (10ml) ON GLASS COLUMN PACKED WITH 1.5% OV-17+1.95% QF-1 ON GAS CHROM Q

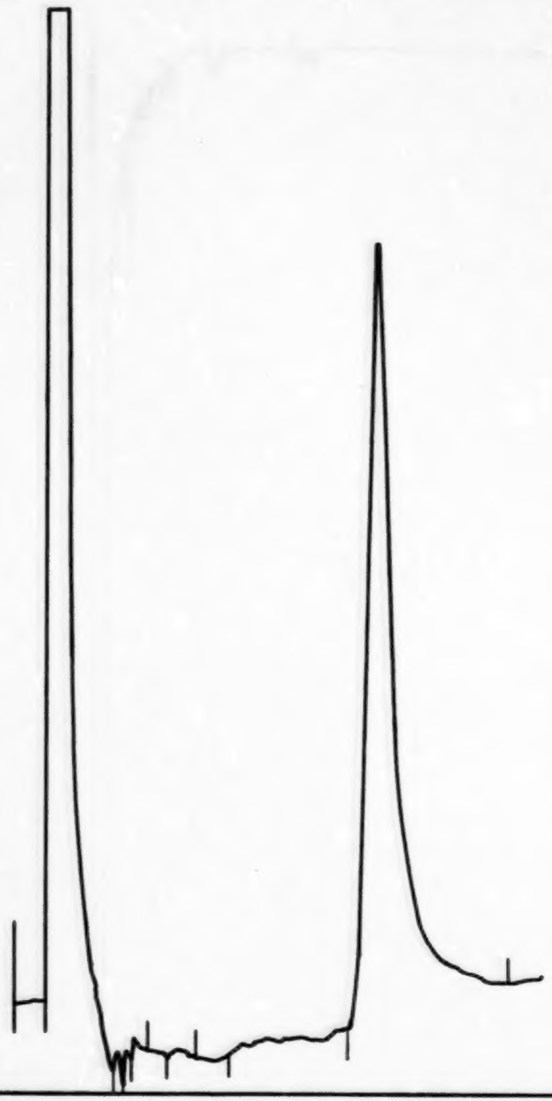


FIGURE F-2
TYPICAL CHROMATOGRAM OF KEPONE ON GLASS COLUMN PACKED WITH 1.5% OV-17+ 1.95% QF-1 ON GAS CHROM Q

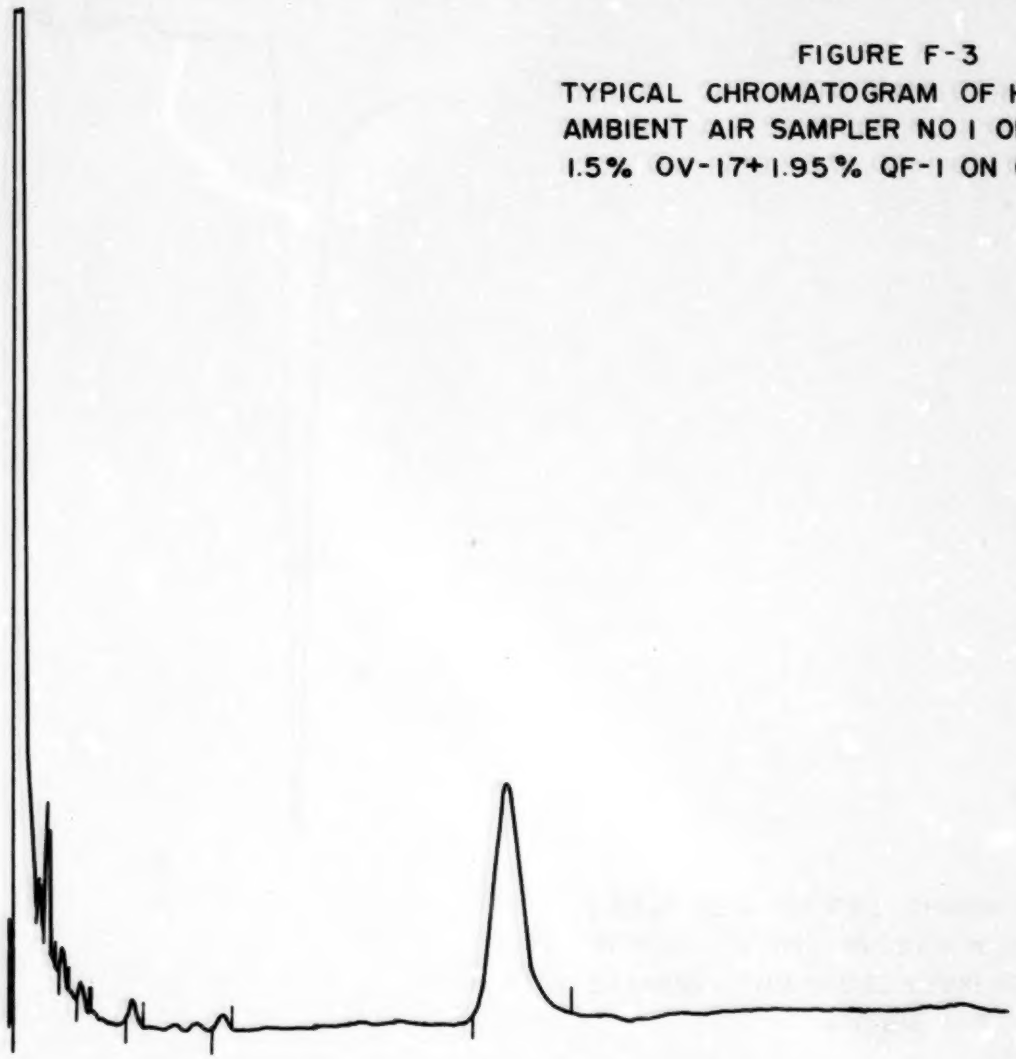


FIGURE F-3
TYPICAL CHROMATOGRAM OF HIGH VOLUME AMBIENT AIR SAMPLER NO I ON COLUMN 1.5% OV-17+1.95% QF-1 ON GAS CHROM Q

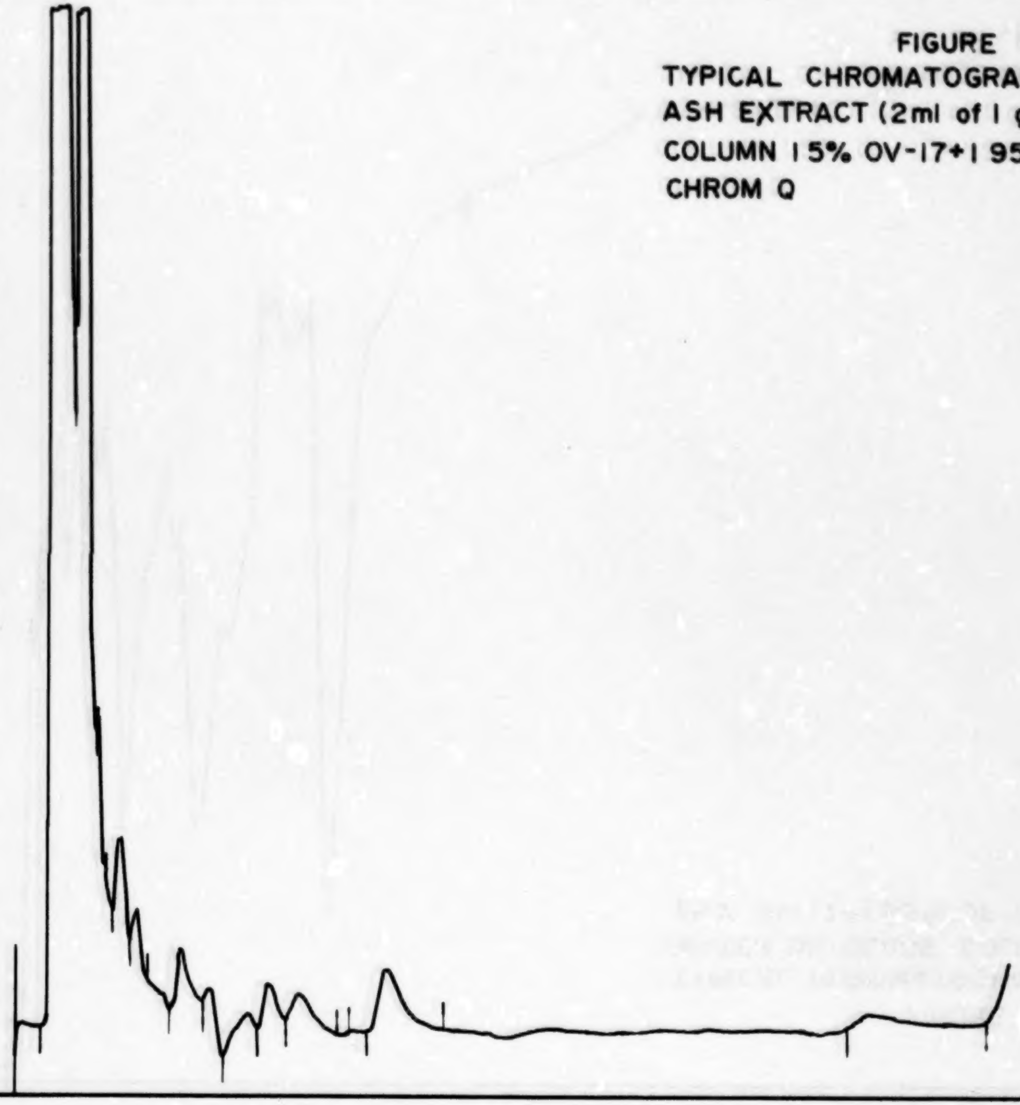


FIGURE F-4
TYPICAL CHROMATOGRAM OF INCINERATION
ASH EXTRACT (2ml of 1 g ash) ON GLASS
COLUMN 1 5% OV-17+1 95% QF-1 ON GAS
CHROM Q

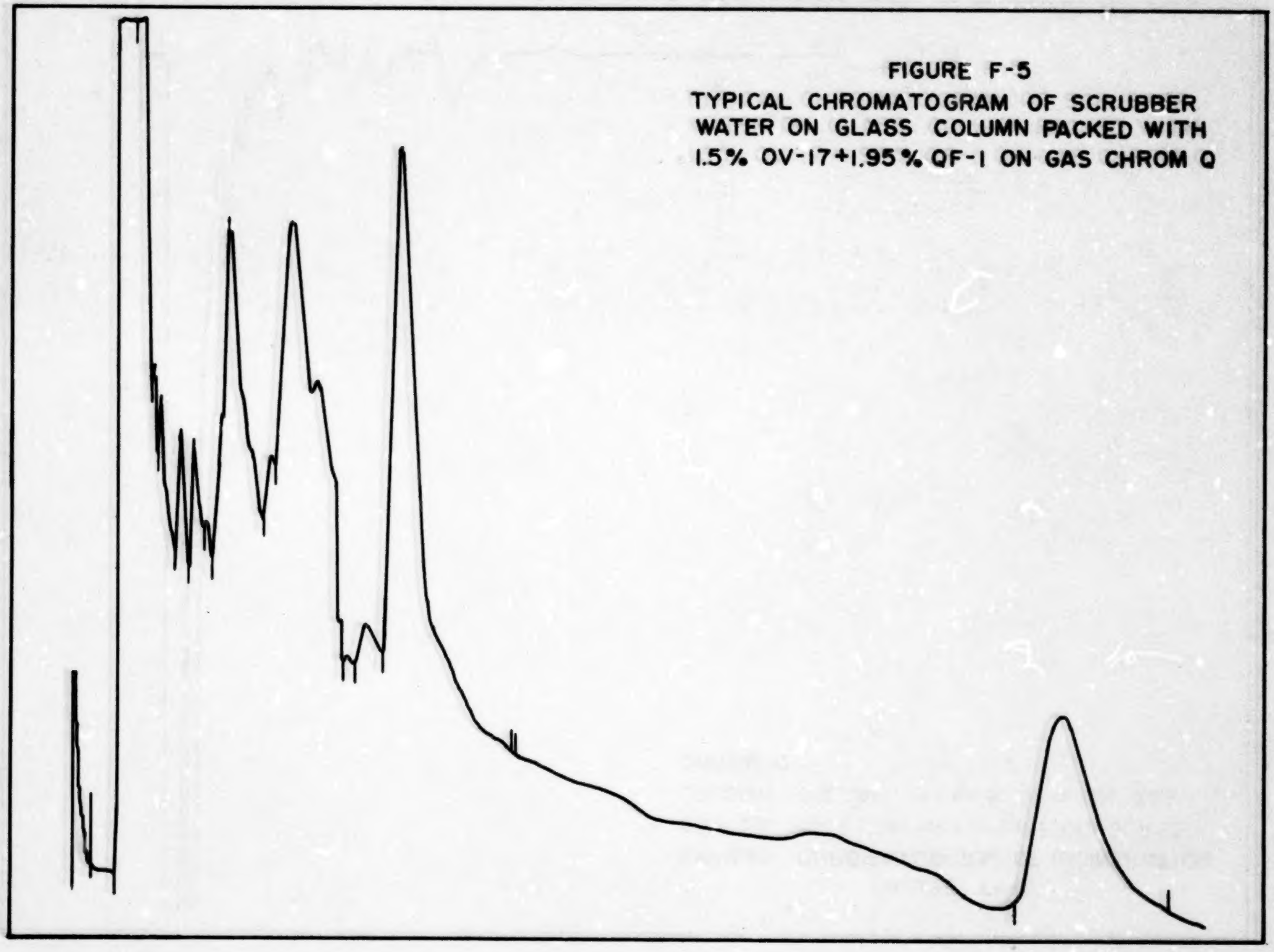
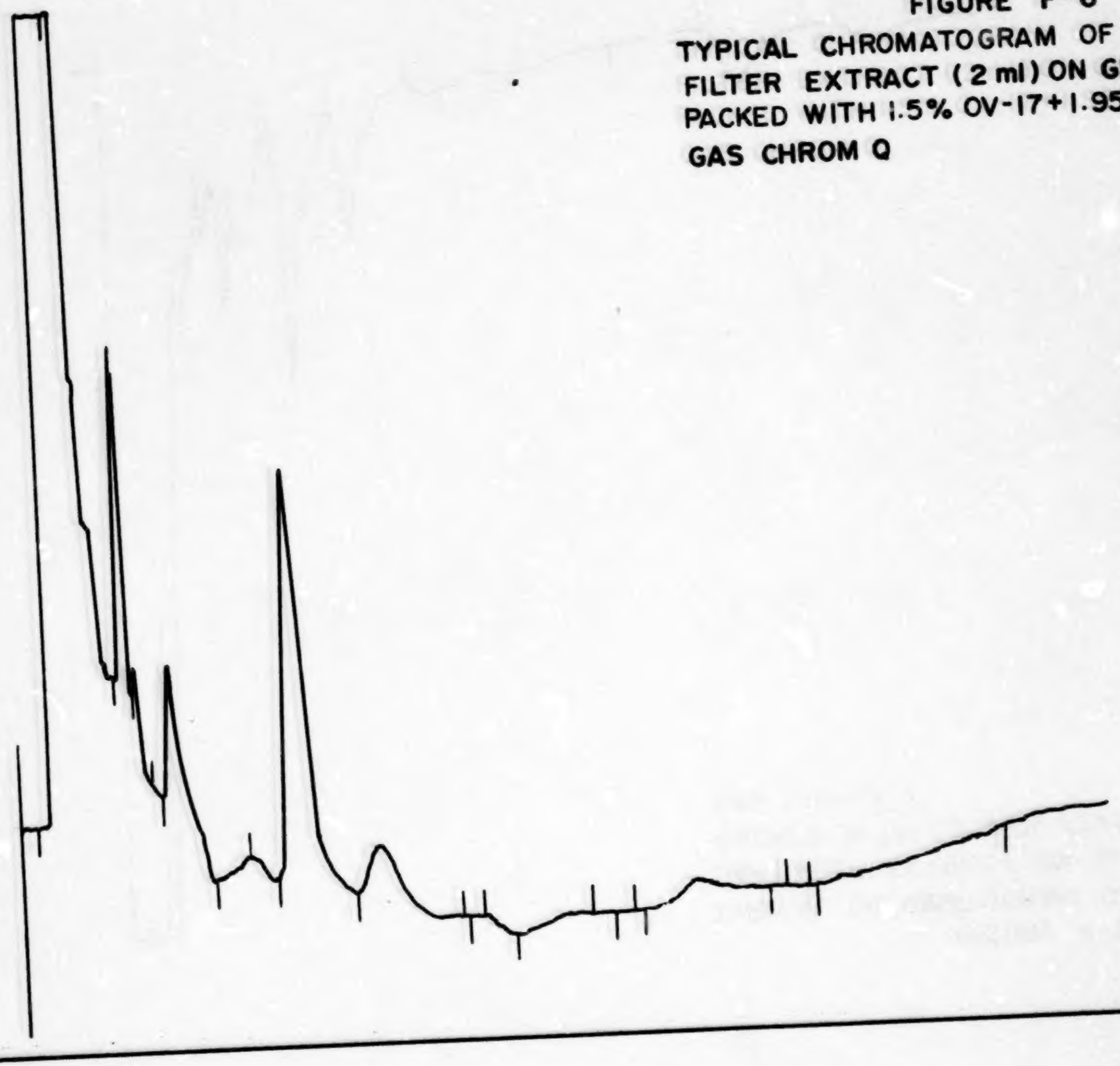


FIGURE F-5

TYPICAL CHROMATOGRAM OF SCRUBBER WATER ON GLASS COLUMN PACKED WITH 1.5% OV-17+1.95% QF-1 ON GAS CHROM Q

FIGURE F-6

TYPICAL CHROMATOGRAM OF STACK GASES FILTER EXTRACT (2 ml) ON GLASS COLUMN PACKED WITH 1.5% OV-17+1.95% QF-1 ON GAS CHROM Q



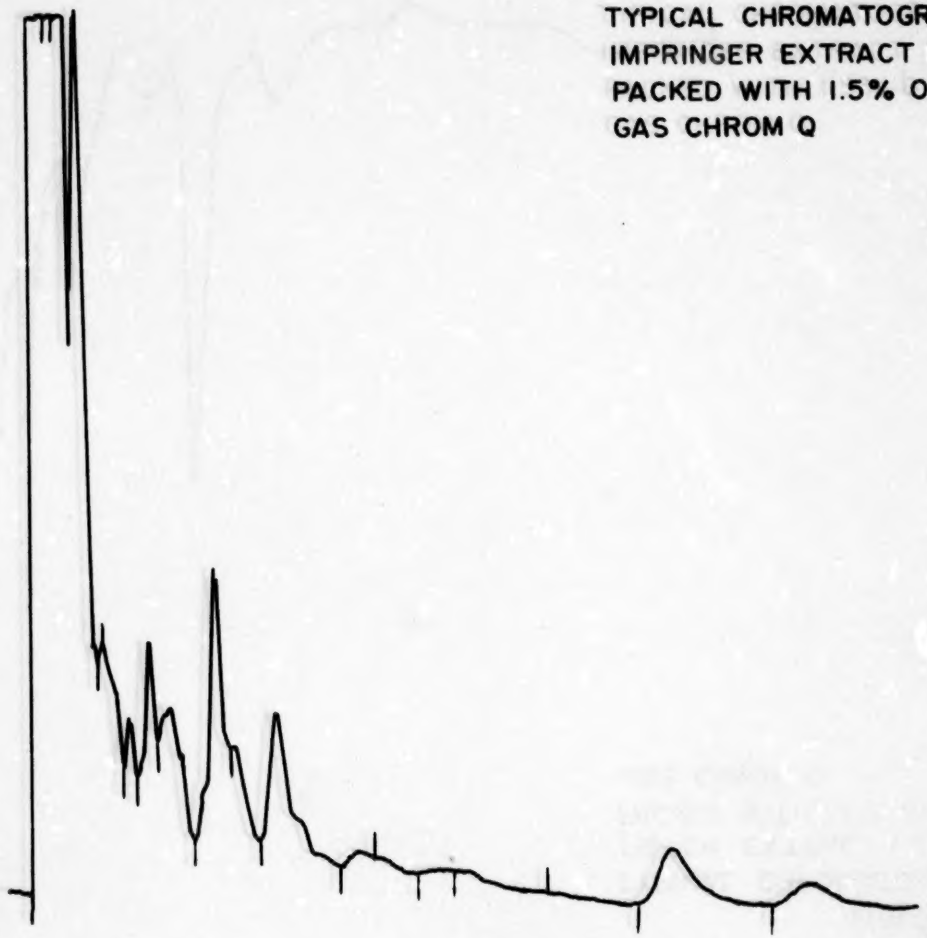


FIGURE F-7
TYPICAL CHROMATOGRAM OF STACK GAS IMPRINGER EXTRACT ON GLASS COLUMN PACKED WITH 1.5% OV-17+1.95% QF-1 ON GAS CHROM Q

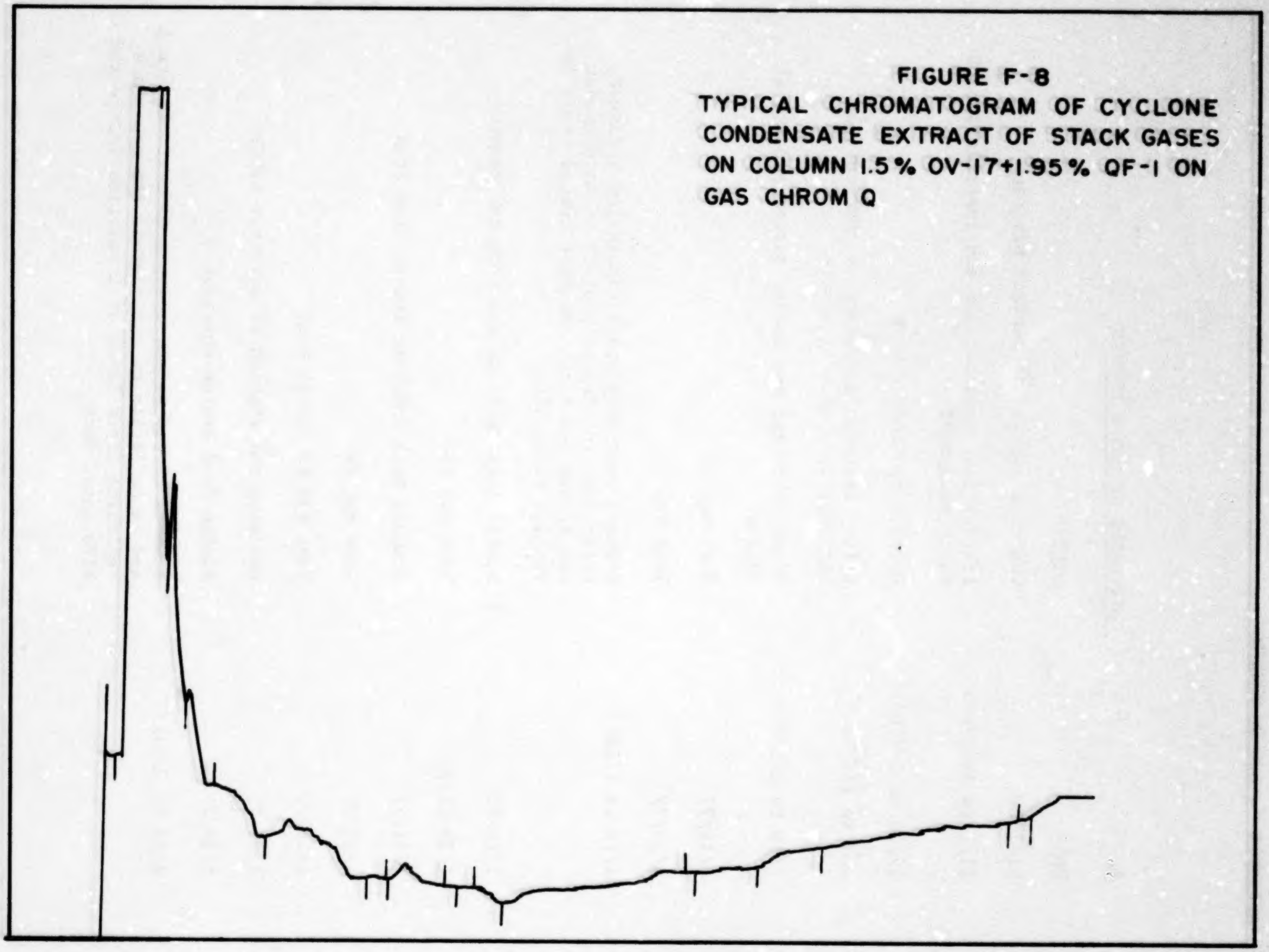


FIGURE F-8
TYPICAL CHROMATOGRAM OF CYCLONE CONDENSATE EXTRACT OF STACK GASES ON COLUMN 1.5% OV-17+1.95% QF-1 ON GAS CHROM Q

APPENDIX G. LOG OF EVENTS

A. TIME TABLE OF MAJOR EVENTS

Date	Events
11/1/76	Contract awarded to Surface Division
11/1 to 12/23/76	Fabrication, construction and installation of major equipment
12/26 to 12/30/76	Outside contractor work
1/3 to 1/7/77	Safety training and start-up checkout for Air Pollution Control System
1/10 to 1/13/77	Troubleshooting for burner system electrical wiring
1/14/77	Test Run #1
1/15/77	Test Run #2
1/16 to 1/18/77	Changed over to propane, installed a direct water line for Kepone project as main header had frozen and burst and heat traced newly installed water line
1/19/77	Acetic acid spill in mix room and cleanup
1/20-21/77	Test Run #3
1/24/77	Trouble with removing Kepone from drum
1/25/77	Test Run #4
1/26/77	Test Run #5 (blank run)
1/27/77	Draining and rinsing of scrubber system
1/28/77	Sludge feed system checkout
1/31 to 2/11/77	Removal of old stack, installation of new stack and installation of a burner in the new stack, replacing inner layer of insulation inside the kiln inlet duct

Date	Events
2/14/77	Test Run #6 (insulated feed line)
2/15-16/77	Water jacketed feed line installed, and a water trough installed around the kiln inlet duct to reduce hot spots
2/17/77	Test Run #7 (kiln rotation stopped after 20 minutes of feeding)
2/18/77	Test Run #8
2/22/77	Broken axle replaced for kiln drive system, frozen core in sludge and required hard work to chip it off - it was too late to make a run
2/23/77	Test Run #9
2/24/77	Test Run #10
2/25/77	Test Run #11
2/26 to 3/4/77	Major clean-up of test area
3/7 to 3/11/77	Minor clean-up
3/14-15/77	Final clean-up and tearing down of the walls in control area

B. SUMMARY DESCRIPTION OF KIT RUNS

Run #1 (1/14/77)

Kepone solution in acetic acid with a concentration of 0.1 mg/l injected into duct at a rate of 9 l/hr and vapors incinerated at 1260°C. for a period of two hours. The kiln outlet temperature was maintained at 538°C for entire test run.

Calculated residence time in the incinerator was 2.15 seconds at the maximum flow rate through the incinerator. (Air leakage into the system is not considered for this calculation in all runs.)

Run #2 (1/15/77)

Kepone solution in acetic acid with a concentration of 0.1 mg/l injected into duct at a rate of 9 l/hr and vapors incinerated at 1093°C for a period of two hours. The kiln outlet temperature was maintained at 538°C.

Calculated residence time in the incinerator was 2.38 seconds at maximum flow rate through the incinerator.

Run #3 (1/22/77)

Fuel system changed to propane gas because of shortage of natural gas. A separate, heat traced water system installed as the main water heater had frozen and burst. Kepone solution (0.1 gm/l) injected into duct at 9 l/hr and vapors incinerated at 1093°C for 1 hour, 40 minutes.

Calculated residence time was 2.39 seconds at maximum flow rate through the incinerator. The kiln outlet temperature was in the range of 533 - 538° C.

Run #4 (1/25/77)

Versar personnel had difficulties in removing Kepone from the storage drums as it had lumped, so the run was made at a lower concentration than planned. The concentration of the solution was 10 gms/l and it was injected into the duct at a rate of 9 l/hr for 1 hour, 40 minutes. The vapors were incinerated at 1093°C.

Calculated residence time in the incinerator was 2.44 seconds at maximum flow rate. The kiln outlet temperature was 538°C.

Run #5 (1/26/77)

Detectable levels of Kepone were observed by Versar in stack and scrubber during run #4. No Kepone solution was injected for run #5, but sampling was carried out for this blank run to understand the causes of detectable levels of Kepone during run #4. Scrubber system drained and rinsed with water after the run as 25 mg/l of Kepone was detected in scrubber liquid.

Run #6 (2/14/77)

A new alloy stack equipped with a 0.147 J/sec capacity burner was installed to prevent water condensation in the stack. Toledo sewage sludge was fed through 1.27-cm line into kiln at a rate of 0.01 liters/sec for about 2 hr. The feed line into the kiln was plugged after about 1 1/2 hr of feeding. The incinerator was operated at 1093°C , and kiln outlet temperature dropped from 482°C to 410°C and again came up to 515°C.

Calculated residence time in the incinerator was 2.06 sec. Hot spots observed on the duct from burner to kiln inlet.

Run #7 (2/17/77)

An insulated feed line was tried prior to this run and a water jacketed feed line was installed. A water trough was installed around the duct from burner to kiln inlet to keep the duct cool. Twenty-five liters of Kepone solution (117 gm/liter) were added to drum of Toledo sewage sludge. The Kepone sludge mixture was fed to kiln at a rate of .0078 liters/sec for 20 min and retort rotation stopped. Feed was stopped and retort drive system repaired. Four bolts and a bolting pad were broken. Bolts were replaced and the pad rewelded.

Run #8 (2/18/77)

The Kepone sludge mixture prepared for run #7 was used for feed. The mixture was fed at an average rate of 0.009 liters/sec for 5 hr. The incinerator was at 1149°C and kiln outlet temperature dropped from 388°C to 310°C and came back up to 329°C. Residence time in the incinerator was calculated to be 2.18 sec at maximum flow rate.

Run #9 (2/23/77)

The friction drive roller had worn out as the axle was broken and was replaced. The sludge had a frozen core and had to be broken loose. The operator used a wrong mark on the measuring stick and transferred only 12 liters of Kepone solution instead of 25 liters into a drum load of sludge. Kepone sludge mixture was fed to the kiln at a rate of 0.0095 liters/sec for 4 hr. The incinerator was at 1093°C, and the kiln outlet temperature dropped from 343°C to 190°C. Kiln inlet gas temperature was lower as the insulation in the duct from the burner to kiln inlet was blown out and water trough was cooling the inlet gases considerably. The water jacketed feed line was cooling the gases at the outlet. The retort was stopping frequently as oil from the drive chain went into clutch.

Run #10 (2/24/77)

The duct from the burner to kiln inlet was insulated. Burner block refractory was observed to be molten and obstructing the path of gases from the burner. Noisy burner during previous run was due to this obstruction. The clutch was cleaned. Kepone sludge mixture was prepared as in run #9 and was fed into the kiln at a rate of 0.0105 liters/sec for 3.5 hr. The incinerator was operated at 1038°C, and kiln outlet temperature dropped from 399°C to 266°C. Calculated residence time in the incinerator was 2.2 sec.

Run #11 (2/25/77)

Two bolts were replaced for the drive system. Approximately 95 liters of Kepone sludge mixture were left over in the feed tank from run #10. About 59 liters of Kepone solution in acetic acid (117 gm/liter) were added to the Kepone-sludge mixture left in the tank. This mixture was fed to the kiln at a rate of 0.0084 liters/sec for 2.5 hr. The incinerator was operated at 1093°C. Water flow to the jacketed feed line was reduced to get higher temperature at the outlet from kiln. Kiln outlet temperature increased from 454°C to 482°C during the feed time. Calculated residence time in the incinerator was 2.26 sec for maximum flow. Two holes of 0.32 cm diameter were drilled, one at each injection point in the duct, after the feed was stopped and air was blown into duct to clear it from dust.

APPENDIX H. EPA (RTP) CONFIRMATORY ANALYSIS RESULTS AND BLOOD TEST RESULTS

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
ENVIRONMENTAL MONITORING AND SUPPORT LABORATORY
RESEARCH TRIANGLE PARK
NORTH CAROLINA 27711

April 5, 1977

Dr. Mohamad N. Khattak
VERSAR, Inc.
6621 Electronic Drive
Springfield, Virginia 22151

Dear Dr. Khattak:

Listed below you will find Versar percent recoveries for the quality assurance spiked kepone filter samples sent to you by Dr. Moseman. In all cases, other than the blanks, your reported values are lower than the spiked kepone concentrations reported by Dr. Moseman.

Filter Number	EPA Spiked Concentration ng/filter	Versar Analysis ng/filter	Versar % Recovery
004	2500	2200	88
005	1250	760	61
006	0	None detected	--
007	500	360	72
008	1250	960	77
009	2500	1880	75
010	500	430	86
011	1250	950	76
012	0	None detected	--
013	1250	1010	81
014	500	420	84
015	2500	2470	99
016	500	410	82
017	2500	2070	83
		Average	80%

If you have specific questions concerning sample preparation and analysis, please contact Dr. Moseman directly.

Sincerely yours,

Thomas A. Hartlage
Chief, Field Studies Section
Environmental Monitoring Branch
(MD-76)

cc: Dr. Moseman (MD-69)
R. Carnes, EPA, Cincinnati

COMMONWEALTH of VIRGINIA
Department of Health
Richmond, Va. 23219

JAMES B. KENLEY, M.D.
COMMISSIONER

SUBJECT: KEPONE INCINERATION TEST

25 March 1977

Dr. Frank Whitmore
Versar, Inc.
6621 Electronic Drive
Springfield, Virginia 22151

Dear Dr. Whitmore:

We have received the analyses of the blood samples collected before and after the Kepone Incineration Test Program on personnel who were to work on the test program. This is to advise that all samples were-negative and no Kepone was detected.

I would appreciate it if you would pass this information on to the appropriate personnel.

Sincerely,

Eric H. Bartsch

Eric H. Bartsch, P. E., Director
Bureau of Sanitary Engineering

EHB/c